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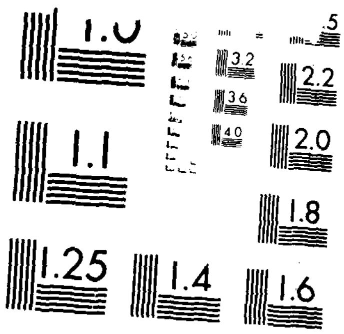


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# CABLE TERMINATIONS

# FOR THE

# BSURE TERMINAL AND TRANSMISSION UNITS

# (TATU)





## DESIGN REVIEW TEAM REPORT

COMPILED BY CHESAPEAKE DIVISION,

NAVAL FACILITIES ENGINEERING COMMAND,

WASHINGTON, DC

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27 Jan 1982. The DRT was tasked to investigate in detail the redesigned BSURE cable termination to determine its mechanical and electrical adequacy for use in the BSURE cable replacement project. A team consisting of representatives from PACMINSTESTCEN (PMTC), CHESNAVFACENGCOM (CHESDIV), and NUSC conducted a design review of the TATU cable termination seals to be used in the BSURE replacement program.

## PREFACE

This is the Design Review Team Report on the Redesigned SD Cable Termination for the BSURE Terminal and Transmission Units (TATU) used in the Barking Sands Underwater Range Expansion In-Water System Replacement Program. The Design Review Team included representatives from the Chesapeake Division, Naval Facilities Engineering Command (CHESNAVFACENGCOM), Washington, DC, the Naval Underwater Systems Center (NUSC), Newport, RI, and the Pacific Missile Test Center (PMTC) at Point Mugu, CA.

Each member organization and its representatives prepared and contributed data contained in this report. The Design Review Team Report was prepared for publication by Chesapeake Division, Naval Facilities Engineering Command, Washington Navy Yard, Washington, DC.

Contributors to this report are R. L. Cox and A. McNairy of CHESNAVFACENGCOM; G. Nussear, R. Polley and Mike Ho of PMTC; R. Ricci and J. A. Millard of NUSC; G. Merry of NOSC; G. MacKenzie of NSWC; Delco Electronics, Santa Barbara, CA; and Columbia Research Corporation, Arlington, VA.

CABLE TERMINATIONS FOR THE BSURE TERMINAL AND TRANSMISSION UNITS (TATU)
DESIGN REVIEW TEAM REPORT

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## CHRONOLOGY OF EVENTS

## THE BARKING SANDS UNDERWATER RANGE EXPANSION PROGRAM

| | |
|---|---|
| 1972 | Requirement for 1000 square nautical mile ($nm^2$) range established by CINCPACFLT |
| 1976 | Installation of 1000+ $nm^2$ range completed by PMTC |
| 1977 | TATU failure in April...TATU failure in September reduced area to 850 $nm^2$ |
| 1979 | TATU failure in February reduced area to 750 $nm^2$...TATU failure in September reduced area to 550 $nm^2$ |
| 1981 | TATU failure in July reduced area to 535 $nm^2$ |
| 1981 | 25-26 August, BSURE In-Water System Status Meeting |
| 1981 | 5-6 November, BSURE In-Water System Replacement Preliminary Termination Redesign Meeting |
| 1981 | December, BSURE Replacement Cable Termination Redesign Tolerance Study |
| 1982 | 13-14 January, BSURE Replacement Program Termination Redesign Final Design Review Meeting |
| 1982 | Failure Modes and Effects Analysis of Redesigned BSURE Termination Sealing System |
| 1982 | Reliability Analysis of the BSURE Redesigned Termination and Integrated Test Program for the In-Water System Replacement Program |
| 1982 | Comments on BSURE Termination Redesign Documentation |
| 1983 | Reliability Analysis of BSURE In-Water Electronics |

# 1.0 INTRODUCTION

1.1 Purpose. The purpose of this report is to document the efforts and analyses of the Barking Sands Underwater Range Expansion (BSURE) In-water System Replacement Design Review Team (DRT) formed by Naval Air Systems Command, AIR-630 letter 630-SL-027 of 5 Nov 1981 and additionally by NAVAIR message 271220Z of 27 Jan 1982. The DRT was tasked to investigate in detail the redesigned BSURE cable termination to determine its mechanical and electrical adequacy for use in the BSURE replacement project. A team consisting of representatives from PACMISTESTCEN (PMTC), CHESNAVFACENGCOM (CHESDIV), and NUSC conducted a design review of the TATU cable termination seals to be used in the BSURE replacement program.

1.2 Background. Requirements established by CINCPACFLT in the early 1970's resulted in the installation of the 1000 $nm^2$ Barking Sands Underwater Range Expansion (BSURE) in 1976 to support underwater tracking of participants in large scale, free-play, multiple-threat AAW, ASW, and ASUW exercises. The BSURE In-water System is comprised of two instrumented cable strings connected to shore. Each string is a series of sensors (multiplexed onto a single type SD coaxial cable) each consisting of a tethered hydrophone above a cable Terminal and Transmission Unit (TATU). BSURE termination failures by 1981 had reduced the operating area to 530 $nm^2$, and further failures would have reduced the area even more. Incident to these TATU failures, COMTHIRDFLT and CINCPACFLT reiterated requirements for the original 1000 $nm^2$ tracking range. Over one-half of the TATUs have been recovered and the failures analyzed. The failures were caused by water leakage in the TATU cable termination seals and were attributed to design/manufacturing deficiencies. The deficiencies were identified, and the cable terminations were redesigned to reduce both the cause and effect of the seal failures.

1.3 Scope. The Design Review Team (DRT) was formed to determine the adequacy of the BSURE electronics design and the redesigned BSURE TATU termination design. The first task undertaken was the review of the failure modes and effects analyses (FMEA) of the cable termination redesign prepared by PMTC. The scope broadened as related components became involved and ultimately included the following:

- o Failure mode and effects analysis (FMEA) of the redesigned TATU termination seals;
- o Investigation of existing seal failure rate data;
- o Investigation of quality requirements for seal mating surfaces;
- o Investigation of program quality assurance requirements;
- o Tolerance of redesigned TATU termination seals; and
- o Parametric reliability analysis of the old and redesigned TATU termination seals.

## 2.0 DESIGN DESCRIPTION

The purpose of the BSURE In-water System Replacement program is to replace the existing degraded and failing BSURE in-water system (Figure 1) with an improved system that would function maintenance-free for a period of 20 years. An important aspect of the replacement system is a redesigned cable-to-TATU termination that provides significantly improved sealing capabilities. As originally designed, the termination (Figure 2) did not provide adequate protection against seawater entering through the cable core or sheath when the outer insulation jacket is cut. The termination redesign (Figure 3), developed and tested by the Pacific Missile Test Center, Pt. Mugu, CA, and Delco Electronics, Santa Barbara, CA, has been shown to protect against these conditions in laboratory simulation tests. The redesign has three features which constitute a significant improvement over the original design: concentric electrical feed-throughs; redundant seals; and pressure equalizing oil-filled cavities.

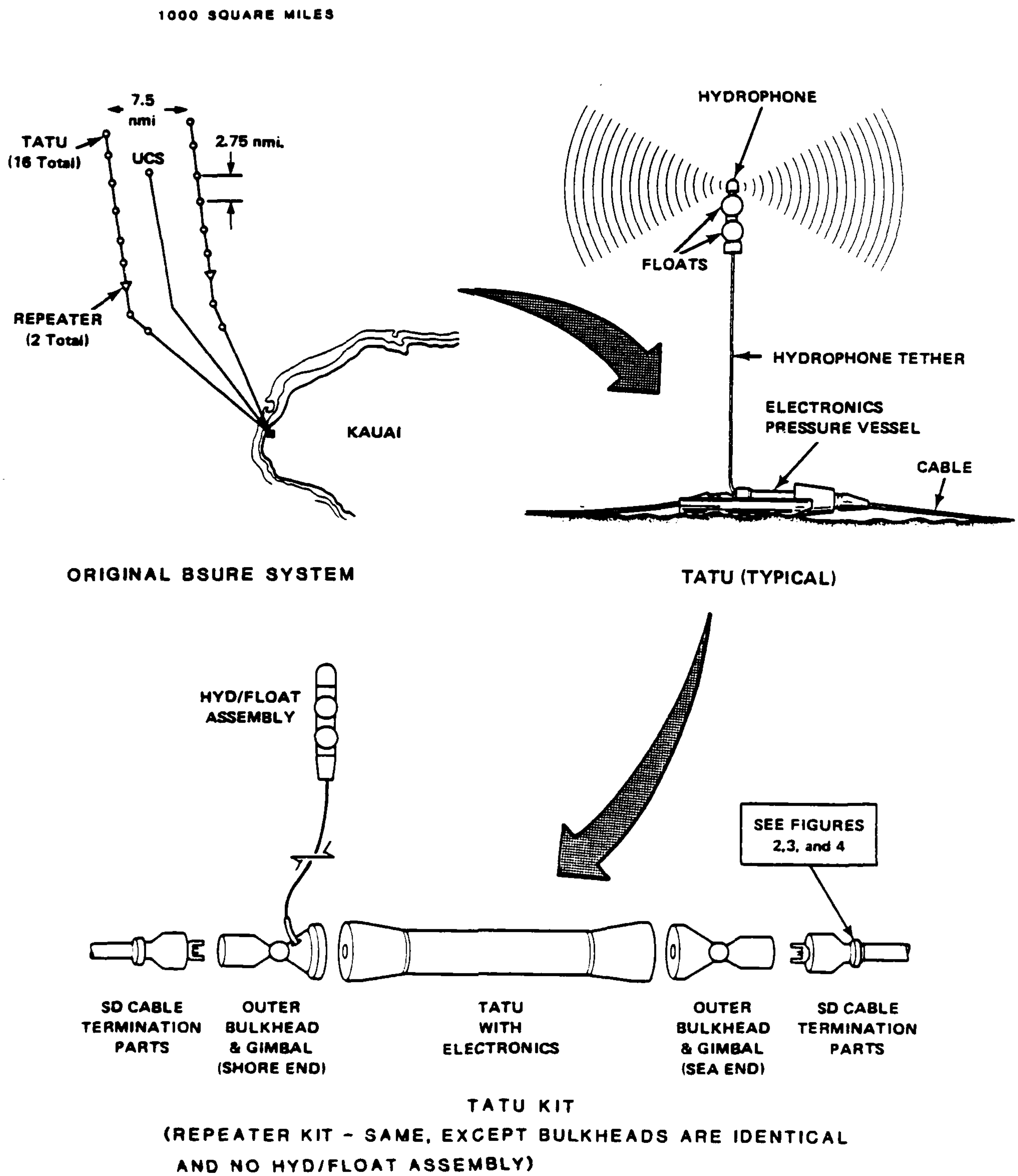


Figure 1. BSURE System

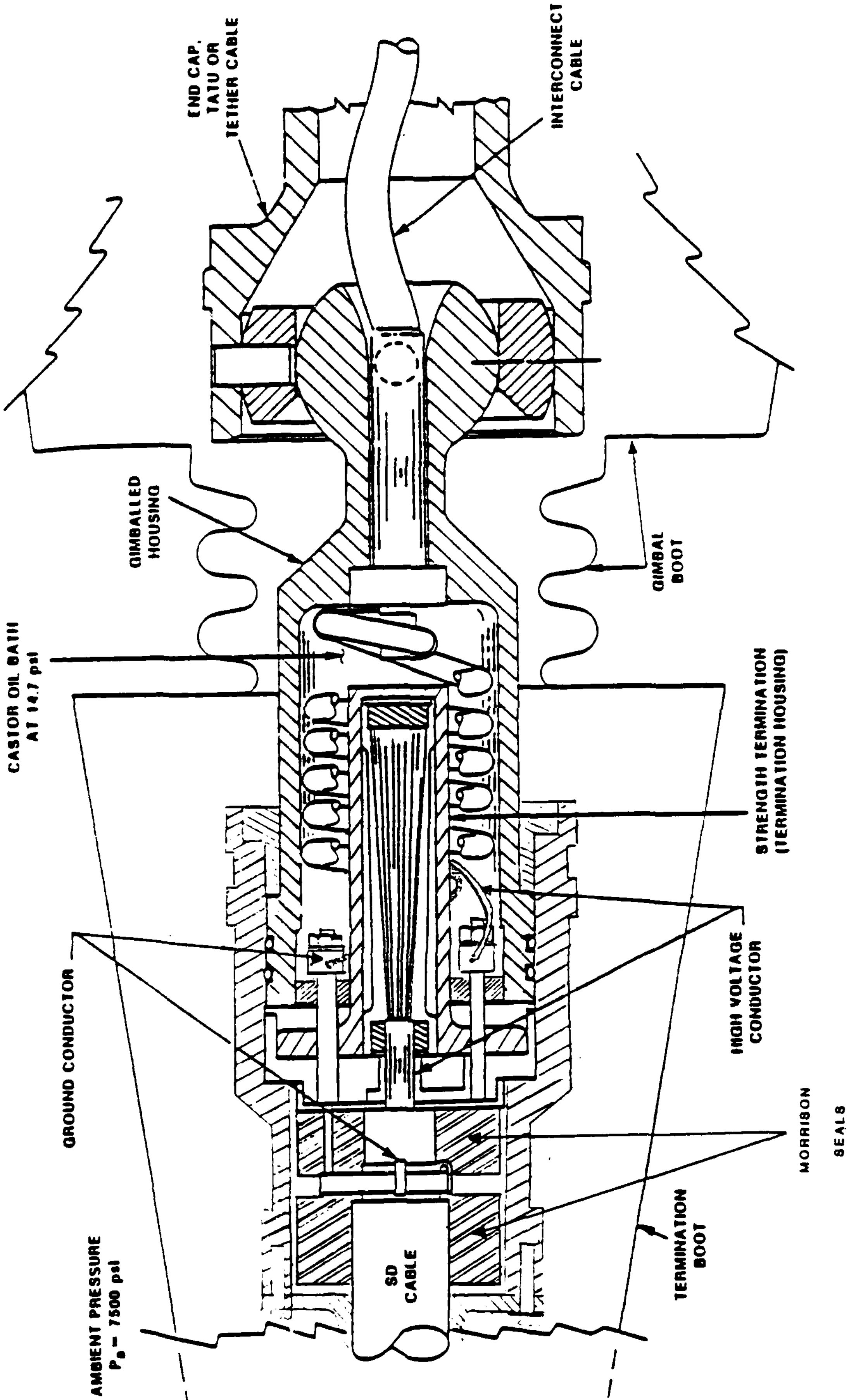


Figure 2. Original Design Termination Cross Section

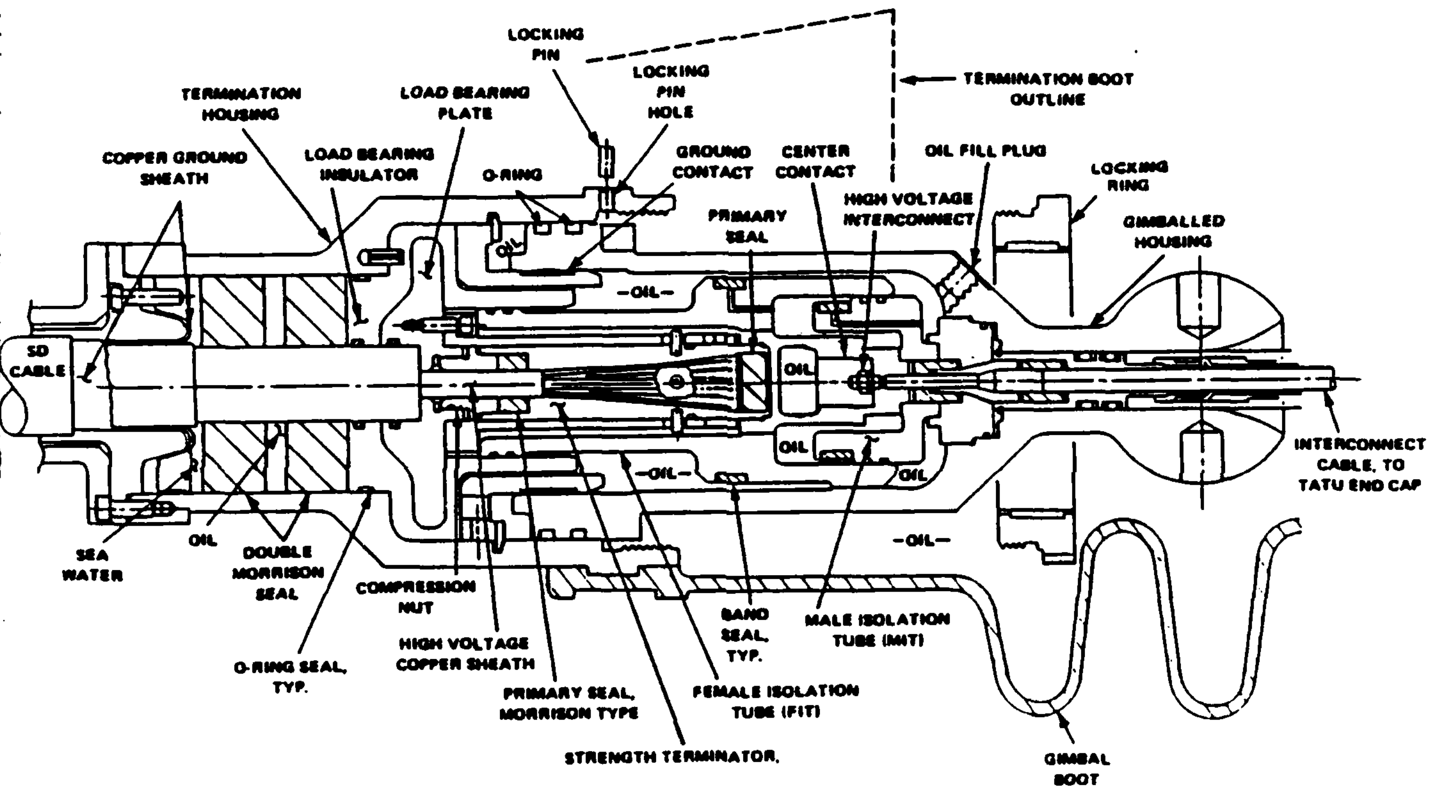


Figure 3. Redesigned Cable Termination Cross Section

In the original design, the copper ground sheath was attached to an off-center pin connected to the coiled cable assembly through a Morrison seal. A leak path developed through this seal as a result of torque experienced by the termination. The torque caused relative rotation between the termination housing and the Morrison seal which in turn caused the pin to move inside the seal. A cable outer jacket leak eventually caused the seal to develop a leak along its interface with the pin which culminated in failure of the termination. In the redesign, the eccentric pin has been eliminated by removing the outer insulating jacket of the SD cable where it enters the termination unit. The copper ground sheath has been folded back and clamped to the metal housing of the TATU to assure reliable grounding of the ground sheath without off-center penetration of the seal.

The redesign intrinsically is more reliable than the original design because it incorporates more redundancy to obtain improved sealing characteristics. In the original design, failure of a single seal could result in failure of the termination unit.

In both the original TATU and the redesign, the termination interconnect housing is filled with castor oil. The redesign, however, provides a mechanism for the oil cavities to be self-pressurizing to the ambient pressure thus reducing the pressure differential across most seals to zero. The oil-filled termination is pressure-balanced by using the gimbal and termination housings as a piston and cylinder, respectively. An air cavity still exists within the cable core, and the differential pressure between the ocean and this cavity (which is at atmospheric pressure) could drive oil into the cable interstices; however, two Morrison seals prevent this from happening.

As shown in Figure 4, the termination consists of two mating assemblies: an SD cable termination assembly and a gimbal assembly. In this figure, the SD

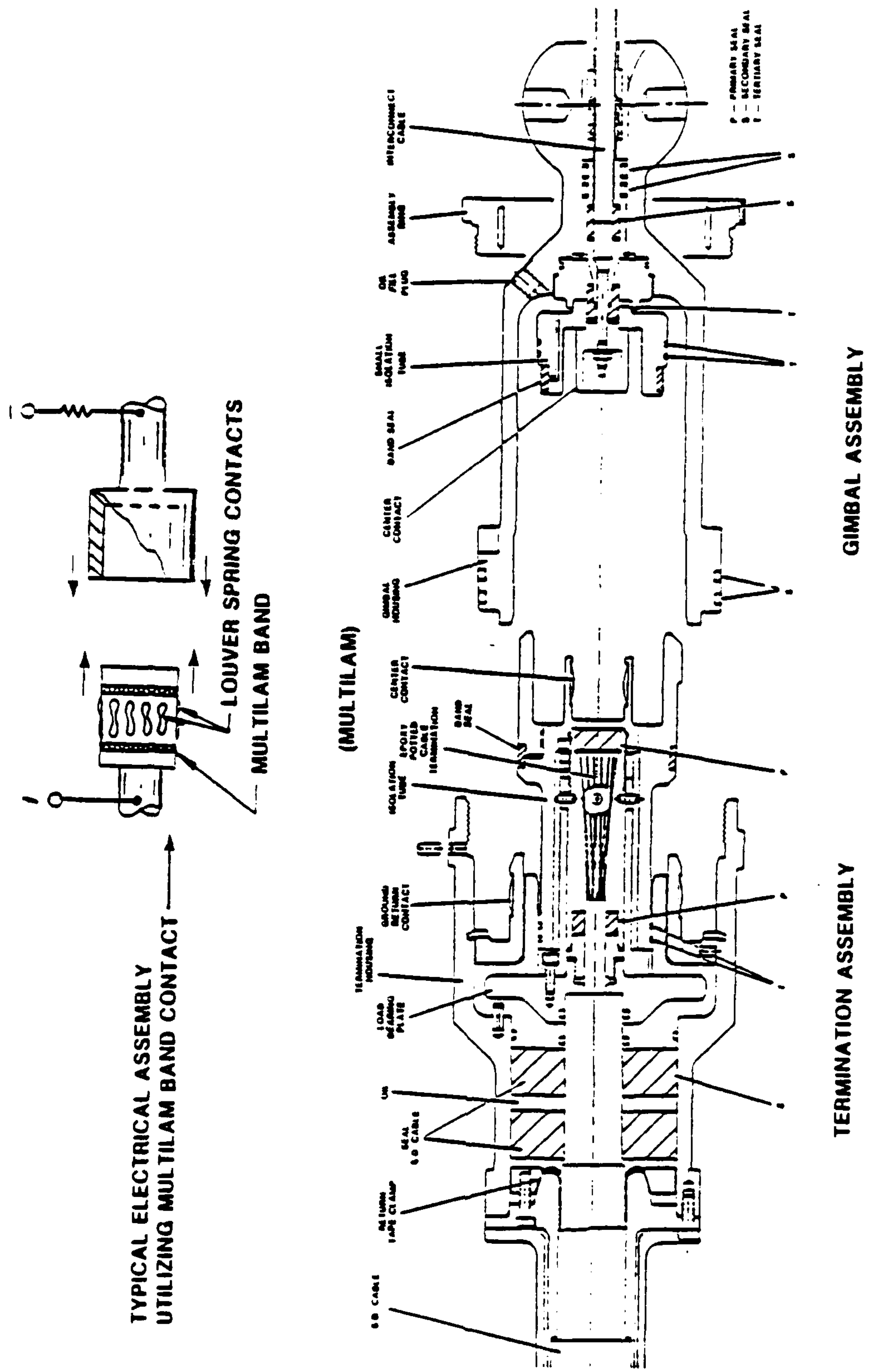


Figure 4. Termination Showing Unmated SD Cable Termination and Gimbal Assemblies. (External Rubber Boot not Shown).

cable enters the termination housing from the left. The outer sheath is removed and the copper ground sheath is folded back and clamped. Seawater is in contact with the copper ground sheath at this point. An underlying polyethelyne dielectric protecting the signal carrier is passed through a pair of Morrison seals separated by castor oil. The polyethelyne dielectric is then passed through the load-bearing insulator and terminates within the load-bearing plate. At the termination of the polyethelyne dielectric the high-voltage copper sheath is exposed and secured to the load-bearing plate by a copper compression fitting. An electrical conduction path is established through this fitting, through the steel load-bearing plate, and then through the strength terminator encasement to the center contact. This contact is achieved through use of a Multilam Band (see accompanying detail in Figure 4), designed and patented by Brown Boveri Co. of Switzerland. The Multilam Band is a flat band formed into a cylindrical shape from heat-treated beryllium copper. The material is processed to provide multiple louver-shaped spring contacts at the mating interface. Thus, a highly reliable electric connection is formed with multiple contacts operating at thousands of pounds per square inch.

The termination also provides a mechanical load transfer between the SD cable and the TATU housing. Axial strength is required during deployment and recovery operations to support the cable in 15,000 feet of water. The rated breaking strength of the cable is 16,000 pounds.

When the two assemblies are mated, an electrical path is completed through the gimbal center contact and the core of the gimbal interconnect cable into the TATU. The assembly ring secures the two termination assemblies and permits relative linear motion to achieve pressure equalization. The male and female isolation tubes (MITs and FITs) are designed with band seals which permit

pressure equalization between the two oil cavities while preventing an electrical path to be completed between high voltage and ground. The outer gimbal boot is also oil-filled as shown on Figure 3.

## 3.0 INVESTIGATIONS AND DISCUSSIONS

3.1 Investigation of Existing Seal Failure Rate Data. An exhaustive search was conducted by the DRT members to acquire data such as manufacturers' test reports and test reports on other systems using Morrison seals in order to establish a failure rate. No meaningful data was found (see Appendix A, Item 6). This obstacle was overcome by using the failure rate of the old seal design.

3.2 Investigation of Quality Requirements for Seal Mating Surfaces. To support the reliability findings of the analysis, NUSC investigated the quality requirements for the machined seal mating surfaces. The investigation (Appendix B, Item 6) indicated that the specifications on the drawings, which control the actual quality during manufacture and inspection, were inadequate in not quantitatively specifying the limits on acceptability. Drawings were annotated: "Indicated surfaces are sealing surfaces and shall be free of axial scratches or other imperfections detrimental to sealing."

Difficulties of this nature would be eliminated by the quality assurance program recommended by the DRT.

3.3 Investigation of Program Quality Assurance Requirements. Preliminary investigations performed by CHESNAVFACENGCOM indicate that:

- The design is well within state-of-the-art manufacturing techniques and practices.

- o It is undetermined if the design is conducive to evaluation tests at various levels of assembly.
- o It is undetermined if the design is overly sensitive to the skill level/ motivation of assembly personnel.
- o An integrated test plan is needed.

CHESNAVFACENGCOM recommended (Appendix A, Item 10) that a Quality Management Team (QMT) be established to oversee the quality assurance program for the BSURE replacement effort. The QMT would assess requirements in areas such as configuration management, documentation, manufacturing, assembly and test.

3.4 Tolerance Study, Redesigned Termination Seals. CHESNAVFACENGCOM performed an initial tolerance study (Appendix C) in December 1981 to determine to what extent it was possible for component part tolerances to build up to the point where the redesigned seals would no longer fit properly. The results indicated that there was a remote possibility for this situation to occur, but that the tolerance changes required to eliminate this were minor; NUSC confirmed this possibility. One solution was that in the event the situation should occur during assembly, resolution would be to interchange parts to provide an adequate seal. This solution was ruled out in favor of changing the drawings to reflect the required tolerance changes because production had not yet begun. CHESNAVFACENGCOM's initial tolerance analysis was checked by PMTC (Appendix D) and DELCO (Appendix E) confirmed the tolerance problem. A final analysis based on the latest drawings was performed by DELCO, PMTC's contractor.

3.5 Failure Modes and Effects Analysis (FMEA), Redesigned TATU Seals. The PMTC team prepared a FMEA (Appendix F) on the TATU connector redesign and the old TATU seals. A FMEA is intended to:

- Examine all potential failure modes and their causes.
- Assess the reliability status of the various elements of the system.
- Assess the effect of each failure mode on system operation.
- Indicate any need for design modification (based on facts disclosed under the items above).

The FMEA answered these items and was centered on possible failure modes, except that it did not determine the reliability of the seal redesign. The FMEA did provide the DRT with insight to the reliability problem and served as a base to determine what other analyses would be necessary.

3.6 Reliability Analyses, Old and Redesigned TATU Seals. Since independent historical seal failure data could not be found, the DRT made an engineering judgement that analyses comparing the actual old seal failures to the predicted redesign seal failures would be the most practical approach to determine the reliability of the seal redesign. CHESNAVFACENGCOM performed a reliability analysis in November 1981. NUSC performed a similar analysis using a slightly different equation. A comparison of the results of the old seal and redesign seal analyses by both team members (Appendix G, Item 7; Appendix A, Item 8) indicates that the redesigned seal intrinsically is 100-500 times more reliable than the old design. Pertinent details of the analyses are presented below.

Assumptions: Due to the lack of applicable data for elastomeric seals (paragraph 3.1), the following simplifying assumptions were used to govern the approach to the analyses:

- Constant Failure Rate for Morrison Seals and O-Rings. It is assumed the Morrison seals and O-rings have a constant failure rate. This assumption is frequently employed in reliability analyses and very little error is caused by its use.

- Identical Failure Rate for all Seals. Because applicable failure rate data was not available, it was assumed that all seals have identical failure rates. There are similarities in the design, elastomeric composition, application, and environment of all the seals. Both designs employ both types of seals. It therefore appears that this assumption is valid for these analyses.

- Negligible Effects Due to the Oil. The effects of castor oil on the failure rate of the seals were disregarded in these analyses. As an engineering judgement, it is believed that the use of oil in the redesign will have beneficial effects on the reliability of the termination unit seals. In the redesign, the oil is pressurized to ambient causing a zero-pressure differential across most of the seals. Therefore, the actual reliability of the redesign will be better than the results of these analyses indicate.

Approach to Analyses:

- Assess the reliability of the old seals, based on 1,947,640 hours of actual operation, and predict the reliability of the old seals over a 20-year period.
- Then, using the same failure rates as used for the old seals, predict the intrinsic reliability of the redesigned seals over a 20-year period.
- Then compare the results of the two analyses to determine if the seal redesign is intrinsically more reliable than the old design.

Results. A comparison of the results of the analyses indicates that the seal's redesign is 100-500 times more reliable than the old design. Comparison tables are presented in Appendices H and I.

## 4.0 RELIABILITY ANALYSIS AND INTEGRATED TEST PROGRAM FOR THE REDESIGNED BSURE TERMINATION

4.1 Reliability Analysis. Columbia Research Corporation (CRC) conducted a reliability analysis of the termination for NUSC (Appendix H). In this analysis, reliability equations for the redesign and original termination designs were developed from system block diagrams and success state tables. The equations were solved for hypothetical reliability values of Morrison seals and O-rings. A comparison of the reliability performance characteristics of the redesign and original designs was then made. This comparative analysis confirmed the superior reliability performance of the redesign.

4.1.1 Assumptions. Due to the lack of applicable reliability data for elastomeric seals, the following simplifying assumptions were used to govern the approach of the reliability analysis:

- Constant Failure Rate for Morrison Seals and O-Rings. The first assumption made for the analysis is that the Morrison seals and O-rings have a constant failure rate. This assumption is frequently employed in failure rate analyses and very little error is caused by its use.
- Identical Failure Rate for all Seals. The second assumption is that all seals, Morrison seals and O-rings, have identical failure rates. This assumption was made because actual failure rate data for these components could not be located. Since there are similarities in the design, elastomeric composition, application, and environment of both Morrison seals and O-rings, and since both the original and modified designs employ both types of seals, it appears this assumption is valid for a comparative analysis.

- Negligible Effects Due to the Oil. In this analysis, the effects of castor oil on the failure rate of seals have been neglected. It is generally believed that the use of castor oil in the redesign will have beneficial effects on the reliability of the termination unit. In the redesign the oil is pressurized to ambient causing a zero-pressure differential across the seals. The reliability analysis neglects this effect. It is therefore felt that the actual reliability performance of the new design might be better than predicted.

4.2 Reliability Analysis (Success States). The block diagram for the original design and the redesign had been prepared by CHESNAVFACENGCOM (Appendix I) based on the FMEA diagrams prepared by PMTC. Using these block diagrams, all the possible success states of the termination units were listed. A success state is any condition in which the termination unit will function as required even though one or more components have failed. All combinations of failed and functioning components that result in system success comprise the system success states.

4.3 Reliability of the Redesign. From the reliability analysis it was concluded that the redesign is a significant improvement over the original design. The predicted improvement is a result of increased component redundancy in the redesign. Additional performance improvement is expected because the redesigned termination eliminates pressure differentials across all but two seals. The beneficial effects of eliminating the pressure differential were not considered in the reliability analysis. Based on this conclusion it was recommended that the redesigned termination be approved for use in the BSURE and that no further design analysis efforts be conducted unless the need for additional redesign is

subsequently indicated by testing. Two additional recommendations regarding tests were included in paragraphs 5.2 and 5.3 of the CRC Analysis for NUSC (Appendix H).

## 5.0 RELIABILITY ANALYSIS OF BSURE IN-WATER ELECTRONICS

5.1 Reliability Analysis Study. It was apparent from a study of BSURE in-water electronics that the Hydrophone/TATU Electronics were suitable for re-use in the replacement program (Appendix A, Item 7).

## 6.0 COMPARISON OF CHESNAVFACENGCOM (PARAGRAPH 3.6) AND NUSC (PARAGRAPH 4.0) ANALYSES

6.1 Comparison Assumptions. The same assumptions were used in both analyses, i.e.:

- o Constant failure rate for Morrison seals and O-rings;
- o Identical failure rate for all seals; and
- o Negligible effects due to the oil.

6.2 Original Design/Redesign Block Diagrams. The block diagrams for the original design and the redesign had been prepared by CHESNAVFACENGCOM and were utilized by NUSC (Appendix I).

6.3 Participants' Conclusions. CHESNAVFACENGCOM and NUSC both concluded that the termination redesign is a significant improvement over the original design. The predicted improvement is a result of increased component redundancy, and additional performance will result from the fact that the unit has been redesigned to eliminate pressure differentials across all the seals but two.

## 7.0 CONCLUSIONS

The results of the Design Review Team's independent analysis, studies, and investigations show that:

- The TATU termination seal redesign is intrinsically 100-500 times more reliable than the old design;
- The intrinsic reliability is considered a fair representation of the actual operational reliability, rovided that the design is not compromised through the use of inadequate controls in areas such as configuration, drawings, manufacturing, assembly, test and inspection, packaging, storage, shipping, receiving, and installation; and
- To ensure the maintenance of reliability standards and the integrity of design requirements for the TATU termination throughout the life of the refurbishment program, that adequate quality assurance controls be established and implemented.

## 8.0 RECOMMENDATIONS

It is recommended that:

- The TATU termination seals redesign be used for the BSURE refurbishment program;
- Adequate quality control procedures be established and maintained throughout the life of the refurbishment program to ensure that the design is not compromised during manufacture and deployment;
- An independent government Quality Management Team be formed to oversee all aspects of the project quality control to ensure that the controls are adequate; and
- A government Quality Management Team monitor the contractor's quality program to ensure that adequate quality controls are implemented and maintained.

APPENDIX A

EXCERPTS FROM THE

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13-14 JAN 1982

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APPENDIX A

EXCERPTS FROM THE
MINUTES OF BSURE REPLACEMENT PROGRAM FINAL DESIGN REVIEW MEETING

1. This meeting was held 13-14 January 1982 at NAVAIR Headquarters. Final design review analyses of TATUs were presented by CHESNAVFACENGCOM (CHESDIV), NUSC and PACMISTESTCEN (PMTC). Action items and future plans were agreed upon prior to adjournment.

2. Mr. Culver and Mr. Crangle (AIR-6303) opened the meeting and discussed the BSURE funding situation. OPNAV has authorized $1.8 M FY-82 O&M,N funds to extend the DELCO contract to refurbish TATUs for a second string and provide initial engineering support.

3. Mr. G. Nussear (PMTC) provided a status report of the 30 September 1981 contract with DELCO. Contract milestones and schedule were reviewed. The additional (second string) contract will be awarded in early February 1982 to DELCO. Target completion date of this contract effort is September 1983. The delay in contract award was caused by the need for review and approval by AC Electronics, Detroit, and DCASMA because of the size of the contract amount.

4. Mr. R. Cox (CHESDIV) presented the results of the Design Analysis Team (DAT) seal tolerance efforts, expressed residual concern and recommended minor changes in the seals. (See covering memorandum, Appendix C.) Mr. R. Polley (PMTC) presented results of their tolerance study of BSURE plug-in terminator (Appendix D). Discussion on the subject attempted to resolve different views of CHESDIV and PMTC. The CHESDIV position was that all O-rings should be reviewed by the government as sufficient questions of compression, cavity and seal size exist to warrant this review. PMTC felt that normal (accepted standards) tolerance ranges and inspection/control procedures should eliminate any problems. Different size sealing components could be changed during assembly as a result of quality control and inspection (QC&I) procedures. It was agreed that changes to QC&I procedures should be made as soon as possible, rather than in the future, as a change to the scope of the DELCO contract would be more costly later.

5. Mr. R. Cox (CHESDIV) discussed the results of the DAT analysis effort and the action items from the preliminary design review (page A-8). Mr. G. Nussear (PMTC) indicated that 95 percent of the "built to" drawing package had been obtained from DELCO. Considerable discussion ensued as to the status of the remaining 5 percent of the drawings and reasons for reluctance or delay on the part of DELCO. It was agreed that every reasonable effort should be put forth to obtain, or to make available for government review at DELCO, the remaining drawings. PMTC has received the seal tolerance analysis from DELCO and will obtain the seal assembly procedures later as a contract deliverable.

6. Mr. R. Ricci (NUSC) reported on efforts to obtain information of seal failure rate data and on accelerated life testing (pages A-9 thru A-12). No failure rate data for seals suitable for analysis was located. Accordingly, the NUSC approach utilized operational data from existing installations. A reliability figure of .916, based on operational data analysis, was derived.

However, this is highly questionable based on approximately 2 million hours on the two existing BSURE strings. Normally, 8-10 million operating hours are considered the minimum for a representative data sample.

7. Mr. R. Ricci (NUSC) presented an assessment of TATU Electronics with predicted system reliability (pages A-13 thru A-18).

8. Mr. R. Cox (CHESDIV) reviewed the CHESDIV model for seal comparative reliability Figure of Merit (FOM) as presented at the previous meeting in November (pages A-19 and A-20). (NUSC had arrived at a very similar model.) Applying the .916 reliability figure derived by NUSC to the models results in a 100- to 500-fold improvement of the new design over the old design.

9. Mr. R. Cox presented a four phase integrated test plan (page A-20). This was followed by a discussion of the quality control (QC) and test functions (pages A-22 thru A-24). NUSC, CHESDIV and PMTC recommended that an independent activity/contractor, preferably located close to DELCO, perform the QC and test of BSURE replacement assembly. The roles and functions of this activity were discussed at length.

10. Mr. R. Cox (CHESDIV) proposed a Quality Management Team (QMT), to operate in a similar manner as the Design Analysis Team, with one representative each from CHESDIV, PMTC and NUSC. This group would be briefed periodically by the QC/Test contractor and meet quarterly in California to review the assembly/installation progress (page A-25).

11. A summary of recommendations was presented by the DAT (CHESDIV, NUSC and PMTC) (page A-26). Discussion followed on BSURE replacement program funding.

12. Action items were discussed and agreement reached on the following:

A. DAT will complete the design analysis, write a report, and begin functioning as the QMT. The team will consist of representatives from PMTC, NUSC and CHESDIV. Mr. R. Cox (CHESDIV) will continue as the team chairman.

B. The DAT will complete the Seal Tolerance Analysis. They will conduct an on-site review of DELCO "build-to" drawings to determine the following: 1) drawing changes should be required to eliminate or relieve potential problems resulting from tolerance build-up or O-ring compression, 2) the extent of such changes recommended (if any), 3) the expected effect of such changes (if any) on the assembly and performance of the TATU, 4) the estimated cost impact of such changes (if any), and 5) a comparison of the effectiveness of any alternative solution to the problems (e.g., parts selection). The DAT will submit a report to AIR-6303 with recommendations and identification of any additional drawings desired to have released by DELCO to the DAT prior to the required contract delivery by 15 February 1982.

C. In conjunction with the DAT's visit to the DELCO facility to review the build-to drawings, the Team will review the TATU assembly instructions/procedures to determine the adequacy of these instructions. They will also determine the need, extent, and feasibility of amending these instructions to include any additional instruction which may be required because of tolerance built up or O-ring compression. These instructions/procedures must be complete and accurate enough to permit the proper assembly of TATUs by an alternate source (other than DELCO). They will submit a letter report to AIR-6303 by 15 February 1982.

D. The DAT will provide inputs to AIR-6303 for the preparation of Project Master Plans (PMP) by 15 February 1982. These inputs should include a brief description of each project task and identification of responsible and performing organizations. Also, the relationship, or interdependence, of the various tasks should be described.

E. NAVAIR will prepare and send a message to the proper Commands describing the disestablishment of the Design Analysis Team and the establishment of the Quality Management Team by 22 January 1982 (complete).

F. QMT will prepare a work statement describing the quality control and test functions required to be performed by the agency (government field activity or contractor) designated as the quality control support agency by 15 February 1982. They will determine if NCEL will accept this responsibility for the BSURE Replacement Project and if such assignment is recommended.

G. The DAT members will provide more refined cost estimates for the various project tasks contained on the BSURE Replacement schedule and funding chart distributed at the 13/14 January design review by 8 February 1982. They will also provide recommendations regarding schedule changes as appropriate.

# AGENDA

## FINAL DESIGN REVIEW OF BSURE REFURBISHMENT PROGRAM

### 13 JANUARY 1982 (WEDNESDAY)

| | | |
|---|---|---|
| 0800-0830 | INTRODUCTION & PROGRAM STATUS | NAVAIR |
| 0830-0930 | DELCO CONTRACT/PROCUREMENT STATUS | PMTC |
| 0930-0945 | INTRODUCTION TO FINAL DESIGN ANALYSIS EFFORTS | CHESDIV |
| 0945-1000 | RESULTS OF PREL. DES. REV. ACTION ITEMS | CHESDIV/PMTC/NUSC |
| 1000-1030 | ASSESSMENT OF TATU ELECTRONICS | NUSC |
| 1030-1130 | RESULTS OF TOLERANCE ANALYSES | CHESDIV/PMTC |
| 1130-1230 | LUNCH | |
| 1230-1330 | RESULTS OF TOLERANCE ANALYSES· | CHESDIV/PMTC |
| 1330-1400 | FAILURE RATE DATA FOR SEALS | NUSC |
| 1400-1430 | BASIS FOR SEAL RELIABILITY ASSESSMENT | NUSC |
| 1430-1530 | UPDATED SEAL COMPARATIVE RELIABILITY FOM | CHESDIV/NUSC |

### 14 JANUARY 1982 (THURSDAY)

| | | |
|---|---|---|
| 0800-0815 | COMMENTS | NAVAIR |
| 0815-1015 | INTEGRATED TEST PLANNING | CHESDIV/NUSC |
| 1015-1130 | QUALITY CONTROL AND TEST FUNCTION | CHESDIV/PMTC/NUSC |
| 1130-1230 | LUNCH | |
| 1230-1300 | QUALITY MANAGEMENT GROUP FUNCTION | CHESDIV/PMTC/NUSC |
| 1300-1330 | SUMMARY OF RECOMMENDATIONS | CHESDIV/PMTC/NUSC |
| 1330-1345 | COMMENTS | NAVAIR |
| 1345-1400 | IDENTIFICATION OF ACTION ITEMS | NAVAIR/CHESDIV/PMTC/ |
| 1400-1530 | CONTINGENCY | |

BSURE DESIGN REVIEW
13 JANUARY 1982

ATTENDEES

| NAME | ORGANIZATION | PHONE AUTOVON | PHONE COMMERCIAL |
|---|---|---|---|
| Mr. R. E. Crangle | AIR-6303 | 222-9182 | (202) 692-9182 |
| LCDR R. Baldwin | AIR-6303A | 222-9182 | (202) 692-9182 |
| Mr. J. Culver | AIR-6303D | 222-9182 | (202) 692-9182 |
| Mr. F. L. Faust | AIR-6103J | | (202) 692-7668 |
| Mr. D. Wickes | NUSC, Code 38214 | 948-3413 | (401) 841-3413 |
| Mr. R. D. Ricci | NUSC, Code 38214 | 948-3415 | (401) 841-3415 |
| Mr. R. L. Cox | CHESNAVFACENGCOM FPO-1 | | (202) 433-3881 |
| Mr. R. Polley | PMTC-3143 | 351-8904 | (805) 982-8904 |
| Mr. G. A. Nussear | PMTC | 351-8904 | (805) 982-8904 |
| Mr. A. Michael Ho | PMRF/PMTC | | (808) 471-6271 |
| Mr. R. S. Clark | SETAC | | (703) 820-9400 |
| Mr. R. D. Erwin | SETAC | | (703) 820-9400 |
| Mr. J. Chastain | SAI | | (703) 524-2053 |
| Mr. M. Di Leo | CRC | | (703) 841-1445 |
| Mr. J. L. Brady | VSE | | (703) 979-4900 X215 |
| Mr. J. M. Hoye | VSE | | (703) 979-4900 |
| Mr. F. Ballinger | PMTC-0143 | 351-8331 | (805) 982-8904 |

Enclosure (3)

# PRELIMINARY DESIGN REVIEW ACTION ITEMS

- OBTAIN "BUILT TO" DRAWING PACKAGE FROM DELCO (PMTC)
- OBTAIN SEAL TOLERANCE ANALYSIS FROM DELCO (PMTC)
- OBTAIN SEAL ASSEMBLY PROCEDURES FROM DELCO (PMTC)
- OBTAIN/SEARCH FOR INFORMATION OF SEAL FAILURE RATE DATA AND ON ACCELERATED LIFE TESTING (NUSC)

CHESNAVFACENGCOM

# FAILURE RATE DATA FOR SEALS

- NO DATA BANK FOR RELIABILITY DATA FOR O-RING OR MORRISON SEALS HAS BEEN LOCATED

- USE OF OPERATIONAL DATA CONSIDERED MORE PRUDENT APPROACH

# SEAL OPERATIONAL DATA

| | |
|---|---|
| A-STRING: TOTAL OPERATING HOURS | 1,176,030 |
| B-STRING: TOTAL OPERATING HOURS | 771,610 |
| | 1,947,640 |

# PROBABILITY OF SUCCESS FOR SEAL
## (DERIVED FROM OPERATIONAL DATA)

$$P(s) = e^{\frac{-t}{MTTF}}$$

WHERE: $t = 175{,}200$ HRS (20 YRS)

$MTTF = 2 \times 10^{6}$ HRS

$$P(s) = .916$$

# ACTION ITEM

- CONTACTED NOS/NSWC RE ACCELERATED AGING TEST PROGRAMS
  - — GARY MERRY, NOS
  - — GERALD MacKENZIE, NSWC
- RECEIVED ENOUGH INFO TO DEVELOP A STRAWMAN TEST PLAN
- NOS/NSWC EXPRESSED WILLINGNESS TO ASSIST IN TEST PLANNING AND IMPLEMENTATION

NUSC

## ASSESSMENT OF TATU ELECTRONICS

- ELECTRICAL AND ACOUSTIC DESIGN DOES NOT INHIBIT OVERALL SYSTEM PERFORMANCE IN THE FORESEEABLE FUTURE
- ELECTRICAL DESIGN FEATURES REDUNDANCY IN SIGNAL PATH
- HYDROPHONE IS EFFECTIVE OVER ENTIRE OPERATIONAL BW OF TATU
- POST EXPERIENCE DOES NOT DICTATE THAT MODIFICATIONS TO THE ELECTRONICS BE MADE

## TATH ELECTRONICS

- FUSE BOARD
- PREAMPLIFIER
- MODULATOR
- BAND COUPLING AMPLIFIER
- POWER SEPARATION UNIT
  (SIGNAL PATH, REDUNDANT)
- FREQUENCY SYNTHESIZER
- CAPACITOR MODULE

## REPEATER ELECTRONICS

- o AMPLIFIER MODULE (SIGNAL PATH, REDUNDANT)
- o PILOT TONE MODULE (REDUNDANT)
- o POWER SEPARATION UNIT (SIGNAL PATH, REDUNDANT)
- o H. V. CAPACITOR MODULE
- o BALUN COUPLING MODULE (SIGNAL PATH, REDUNDANT)

## SEA ANODE ELECTRONICS

- o PASSIVE TERMINATION NETWORK
- o PLATINUM COATED ANODE (DC RETURN)

# ELECTRONICS RELIABILITY

TATU

PROBABILITY OF SUCCESS = 95.55% (20 YEARS)

REPEATER

PROBABILITY OF SUCCESS = 99.86% (20 YEARS)

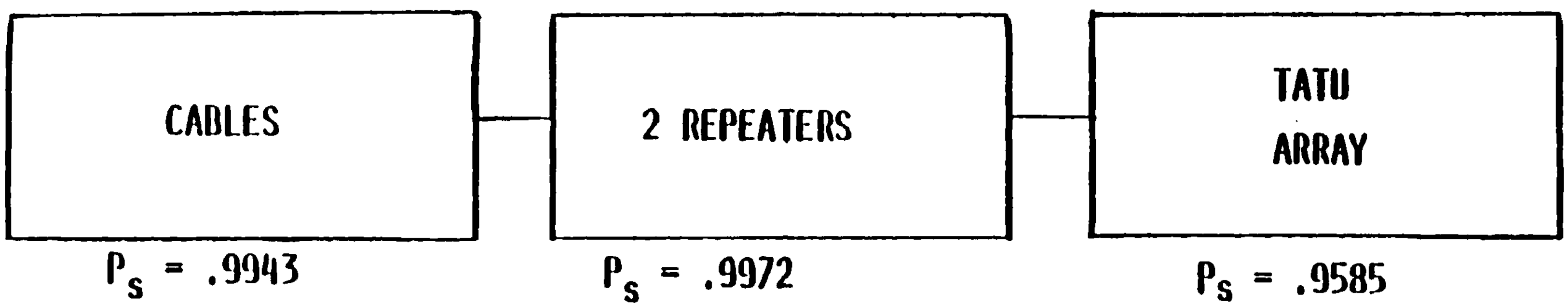
TATU (2 X 8 ARRAY, NO ADJACENT FAILURES)

PROBABILITY OF SUCCESS = 95.85%

CABLES

PROBABILITY OF SUCCESS = 99.43%

## SYSTEM RELIABILITY




$P_s$ FOR SYSTEM = .9504

# PARAMETRIC RELIABILITY ANALYSES

| F | S | PF(OLD) | PF(NEW) | PF(OLD/PF(NEW) | S/F | N |
|---|---|---|---|---|---|---|
| .900 | .100 | .9979 | .9860 | 1 | 0.1 | 0.134 |
| .340 | .660 | .4633 | .8895 | 5 | 1.9 | 2.238 |
| .270 | .730 | .3711 | .0373 | 10 | 2.7 | 2.512 |
| .150 | .850 | .2076 | .0037 | 50 | 5.7 | 2.952 |
| .122 | .878 | .1667 | .00164 | 100 | 7.2 | 3.048 |
| .070 | .930 | .0898 | .00018 | 500 | 13.3 | 3.242 |
| .055 | .945 | .0683 | .00007 | 1,000 | 17.2 | 3.298 |
| .031 | .969 | .0356 | .000007 | 5,000 | 31.3 | 3.417 |
| .024 | .976 | .0270 | .0000026 | 10,000 | 40.7 | 3.448 |

F - PROBABILITY OF FAILURE OF A SINGLE SEAL OVER 20 YEARS

S - PROBABILITY OF NON-FAILURE OF A SINGLE SEAL OVER 20 YEARS (1-F)

$P_F$ - PROBABILITY OF FAILURE OF THE NEW SERIES/PARALLEL MULTI-ELEMENT SEAL OVER 20 YEARS

N - EQUIVALENT SERIES SINGLE SEALS THAT GIVES THE SAME RESULTS AS THE SERIES/PARALLEL MULTI-ELEMENT SEAL (N = LOG PF/LOG F)

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# COMPARATIVE RELIABILITY EQUATIONS

**ORIGINAL DESIGN**

$$P_P = 1-(S)\left[1-(-S^2)(1-S^3)\right]\left\{1-(1-S^3)\left[1-(1-P^2)^2(1-P^3)\right]\right\}$$

**IMPROVED DESIGN**

$$P_{P_1} = P^2(1-S^2)$$

$$P_{P_2} = 1-S^3$$

$$P_{P_3} = (1-S^2)\left\langle 1-\left[1-P^2\right]\left\{1-\left[1-S^2\right]^2 \left[1-(1-P^2)^2\right]\right\}\right\rangle$$

$$P_P = \left[P_{P_3}\right] \left[1-1-P_{P_1}\right) (1-P_{P_2})\right]$$

P - Probability of failure

S - Probability of non-failure (success)

$P+S=1$

# INTEGRATED TEST PLAN

A. FABRICATION PHASE
- — SUPPLIER FACILITIES INSPECTION
- — IN-PROCESS INSPECTIONS
- — RECEIVING INSPECTIONS
- — ACCEPTANCE INSPECTIONS

B. VALIDATION PHASE
- — RECEIVING INSPECTION
- — ASSEMBLY TESTS
- — INDUCED FAILURE TESTS
- — PRESSURE DEMONSTRATION TESTS
- — SIMULATED DEPLOYMENT TESTS
- — IN SITU TEST
- — RELIABILITY

C. INSTALLATION PHASE
- — ASSEMBLY INSPECTION
- — PERFORMANCE MONITOR TESTS

D. SYSTEM INTEGRATION & CHECKOUT PHASE
- — PERFORMANCE MONITOR TESTS

QUALITY CONTROL & TEST FUNCTIONS

1. ASSIST THE QUALITY MANAGEMENT GROUP (QMG) IN THE PREPERATION OF THE INTEGRATED TEST PLAN
2. WORK CLOSELY WITH THE DELCO QUALITY CONTROL GROUP
3. REVIEW THE DELCO "BUILD TO" DRAWING PACKAGE
4. REVIEW THE DELCO DETAILED QUALITY PALN
5. REVIEW THE DELCO MANUFACTURING PLAN
6. MONITOR ALL SIGNIFICANT INSPECITONS/TESTS PERFORMED BY DELCO
7. WORK CLOSELY WITH THE QUALITY CONTROL GROUP OF THE BSURE INSTALLATION CONTRACTOR (BIC)
8. REVIEW THE DELCO TERMINATION ASSEMBLY PROCEDURES
9. REVIEW ALL INSPECTION/TEST REPORTS

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## QUALITY CONTROL & TEST FUNCTIONS (CONTINUED)

10. REVIEW THE DELCO PART/EQUIPMENT STORAGE, PACKING, AND SHIPPING PLAN

11. ESTABLISH A BONDED STORAGE FACILITY FOR PARTS/EQUIPMENT DELIVERED BY DELCO

12. PERFORM DESIGNATED TESTS OF THE INTEGRATED TEST PLAN

13. PERFORM ADDITIONAL PART INSPECTIONS AS REQUIRED TO SUPPORT THE INTEGRATED TEST PLAN

14. INSTRUCT THE BIC IN THE PROPER HANDLING AND ASSEMBLY PROCEDURES FOR THE EQUIPMENT

15. MONITOR THE ACTIVITIES OF THE BIC IN HANDLING AND ASSEMBLING THE EQUIPMENT

16. IMMEDIATELY REPORT THE RESULTS OF ALL INPSECTIONS/TESTS TO THE QMG

## QUALITY CONTROL & TEST FUNCTIONS (CONTINUED)

17. PROVIDE QUALITY PROGRESS PRESENTATIONS TO THE QMG EVERY 3 MONTHS

18. ASSIST THE QMG IN WRITING THE QUALITY MANAGEMENT FINAL REPORT

CHESNAVFACENGCOM

# QUALITY MANAGEMENT GROUP FUNCTION

## TASKS

1. PREPARE AN INTEGRATED QUALITY PLAN
2. PREPARE AN INTEGRATED TEST PLAN (SUBSET OF IQP)
3. WRITE WORK/TASK STATEMENT FOR QUALITY CONTROL AND TEST ORGANIZATION/CONTRACTOR
4. NEGOTIATE QUALITY CONTROL COOPERATION FROM DELCO
5. SELECT/RECOMMEND THE QUALITY CONTROL AND TEST ORGANIZATION/CONTRACTOR
6. PERIODICALLY MEET WITH THE QUALITY CONTROL AND TEST ORGANIZATION/CONTRACTOR AND THE TATU CONTRACTOR TO REVIEW PROGRESS OF THE INTEGRATED QUALITY PLAN
7. PERIODICALLY REPORT TO NAVAIR ON PROGRESS OF THE INTEGRATED QUALITY PLAN
8. WRITE AN INTEGRATED QUALITY PLAN FINAL REPORT

## DURATION — 2nd Q FY-82 THROUGH 4th Q FY-84

## PARTICIPANTS

ONE REPRESENTATIVE EACH FROM:
- CHESNAVFACENGCOM
- PMTC
- NUSC

## ESTIMATED COST

| | |
|---|---|
| CHESNAVFACENGCOM | TBD |
| PMTC | TBD |
| NUSC | TBD |

CHESNAVFACENGCOM

# SUMMARY OF RECOMMENDATIONS

1. PROCEED WITH ACQUISITION OF REFURBISHED TATU'S FROM DELCO

2. ESTABLISH A QUALITY MANAGEMENT GROUP (QMG)

3. HAVE THE QMG PERFORM THE TASKS PREVIOUSLY INDICATED AS THE QMG FUNCTIONS

4. PROVIDE IMMEDIATE FUNDING FOR THE QMG AND Q.C. AND TEST FUNCTIONS

CHESNAVFACENGCOM

# APPENDIX B

# NUSC COMMENTS ON BSURE REDESIGN DOCUMENTATION

NUSC COMMENTS ON BSURE REDESIGN DOCUMENTATION

1. The BSURE redesign drawings have been given a cursory review by both NUSC and CHESDIV. The primary purpose of the review was to determine the accuracy and completeness of these drawings to achieve redesign goals. The design depicted on the drawings appears to represent a viable solution. The redesign validity has been verified by a successful test of a prototype. It could not be verified if the drawings accurately reflected the tested prototype. In all probability, they do not.

The design depiected on the drawings was reviewed in some detail particularly in the areas of the Morrison seals and the 'O' rings. The investigation did not reveal any obvious flaw in the design or in the use of these seals. This review included a tolerance variation assessment and its effect on the proper function of the seals.

2. The general category of the Delco drawings reviewed, tends to fall into the LEVEL 2 category as defined by DoD-D-1000B. This assessment is based on the fact that many component materials are specified in terms of internal Delco specifications, supplier identification, or general industry nomenclature without specific control reference. In addition, a few key fabrication operations are controlled and qualified by the use of special Delco tool gages. The drawing package references a few tests at assembly, but these tests appear to be minimum in scope and are part of the original design package and may be inadequate and/or inappropriate for the redesign version.

3. The drawing package depicts a design which utilizes extremely complex components containing many precision dimensions which require extreme care in methods of fabrication and inspection. The Quality Assurance Program, due to be submitted for approval 30 days after contract award, is the key document to insure proper fabrication and inspection of all deliverable components in accordance with the drawing package. The Government should review this submittal with care before approval of this document is given.

4. Three drawings are referenced in the contract as defining the deliverable items. These drawings are 7556614 for TATU refurbishment, 7556615 for REPEATER refurbishment, and 7556616 for anode rework. These drawings were not part of the documentation package available for review, therefore, a top-down breakdown of the family tree could not be made. From the contract and all other information available, an exact determination of the total drawing package and revision status which forms the technical and fabrication base for the contract could not be determined. It is essential that the total contract documentation package be accurately identified to establish the production baseline.

5. The contract does not formally establish a Configuration Management Program. A CM program is vital to systematically evaluate and implement changes, waivers, and deviations to the production baseline. It is assumed that Delco has an internal CM Program which may be adequate for the goals of this contract. A severe deficiency in the contract is this internal program will function without government participation and approval. Government participation is mandatory if in-process and end product control is to be adequately established and maintained throughout the contract.

6. The following are general and/or often repeated comments generated from the drawing review:

a. Many key sealing surfaces are controlled by a drawing note which states: "Indicated surfaces are sealing surfaces and shall be free of axial scratches or other imperfections detrimental to sealing." This statement, although of noble intent, does not quantitively specify the limits of acceptability which may be critical to the design success.

b. Most drawings created in 1980 (756XXXX series) were not checked. These drawings contain signatures of the draftsman and an engineer. A checker's signature signifies a very skilled individual who possesses intimate knowledge of all fabrication methods and drafting standards has reviewed the drawing for completeness, adequacy and accuracy.

APPENDIX C

BSURE CABLE TERMINATION

CHESNAVFACENGCOM TOLERANCE STUDY, DEC 1981

NOTE: The analysis was performed by CHESNAVFACENGCOM using early release drawings provided by PMTC for review. Subsequent analyses conducted to confirm tolerance design problems noted in this study were undertaken by PMTC and DELCO using the final release drawings. PMTC and DELCO analyses are provided in Appendices D and E. Apparent tolerance problems noted in the CHESNAVFACENGCOM analyses which resulted from use of early release drawings were identified by PMTC and provided to CHESNAVFACENGOM for information. Design changes were made by DELCO to correct tolerance problems noted by CHESNAVFACENGCOM and confirmed by PMTC and DELCO.

FPO-1HF3:mak
29 December 1981

MEMORANDUM

From: FPO-1HF3
To: FPO-1FP4

Subj: BSURE Cable Seal Tolerance Study

Encl: (1) Tolerance Study Calculations

1. A study has been conducted of the Delco Electronics drawings of the BSURE cable termination. The purpose of this study was to determine if there was any possibility, however remote, of any seal leakage in the hardware fabricated and assembled from these drawings. While the effort was burdened by the absence of an assembly drawing and any documentation describing assembly procedure, it was possible to determine that potential for leakage could exist, mostly in the secondary seals. It should be recognized that the leakage would result from tolerance build-up under the worst possible combinations, since such a situation could exist although admittedly unlikely.

2. Enclosure (1) first addressed the Morrison-type seals, numbers 30, 26, 20, 14, 2 and 1 as shown on page 28. This effort was made to determine if there existed any possibility of the seals having greater volume than that available in their cavities. This situation exists for several seals so the effects of the resulting displacement of members forming the seal cavities were investigated. This effect can make at least one of the secondary seals ineffective.

Second, the O-rings, seals number 33, 29, 23, 16, 15, 13, 12, 7, 5, and 4 were checked for maximum and minimum compression, including the effect of stretching. In addition, each O-ring was evaluated for relative volume compared to available volume in the O-ring grooves. In general, the maximum compression was extremely high, considerably above accepted standards, although such standards do not appear to be finite for such static seal applications. In addition, some of the seals can occupy a very large percentage of the available volume in the grooves, approaching 90%. Thus, they must change from a circular to an almost square cross-section. It would seem that both of these problems could result in difficult assembly problems and possible seal material deterioration with time.

The two band seals, numbers 21 and 19 were checked also. No potential problems were apparent.

3. Enclosure (1) has uncovered the following sealing problems:

a. <u>Morrison-Type Seal No. 30 Installation:</u> This seal can be 3.2% volumetrically more than the available volume, or probably greater than this

if a minute amount of metal compression occurs in the taper joints. This can cause a gap of .0142 inches minimum between pieces number 27 and 32 and possibly as high as .05 inch. Since a gap of only .017 inch will result in O-ring seal number 29 being exposed and thereby ineffective, it is recommended that the nominal .36 inch seal width be reduced to a nominal .30 dimension. In addition, the assembly procedure should include an accurate measurement to determine that piece number 27 is actually bottomed against piece number 32, which would indicate that the gap problem does not exist.

b. Morrison-Type Seal Number 26 Installation: This seal will not exceed the available volume in the seal cavity. However, there is a seal back up ring drawing number 7564009 which appears to fit this cavity, although this is not clear from the drawing. If indeed it is installed with seal number 26, their combined volume will exceed the available volume by 3%. This will cause gapping between piece number 25 and 27. While this will not present a seal problem, it will have the effect of backing piece number 17 out of the termination housing, piece number 9. This is undesirable, so measurements should be taken at assembly to ascertain that the gap does not exist. If it does, the length of seal number 26 should be reduced, or possibly leave out the seal back-up ring.

c. Morrison-Type Seals Numbers 14 and 20: These are the primary seals, and as such, warrant maximum attention during assembly. Seal number 20 and the seal described by drawing number 7563620 can extend .013 inch into the taper of piece number 18. It is not known if this could present an assembly problem, since the depth of the potting for cable strength members in this taper is unknown.

Seal number 14 can require more volume than available in the seal cavity, causing a .030 inch gap between piece number 18, the cable terminator and the compression nut. This does not appear to present a problem when using the number 20 seal shown on drawing number 7563620-001. However, the -002 seal on this drawing is .80 thick instead of .31. It is much too thick for this installation. It's use is unknown.

d. Morrison-Type Seals Numbers 1 and 2: There are no apparent problems relative to volume versus available space for these seals.

e. O-Ring Seals: The enclosed calculations show O-ring compression as high as 47% maximum and 18 1/2% minimum. These figures are slightly high, since they do not take into account the slight oval cross section which the rings assume when stretched the order of 3% when installed. However, the amount of compression is very much higher than one authority's normally accepted maximum compression of 24% and minimum compression of 17% for static O-rings.

FPO-1HF3:mak
29 December 1981

Subj: BSURE Cable Seal Tolerance Study

It is not known if this presents a problem, other than the obvious difficulty in assembly. In addition, some seals, such as numbers 12 and 13 can occupy 87 1/2% of the rectanglualr o-ring cavity. The absence of "ramps" or bevels on some pieces must really complicate assembly when such a high percentage of the seals must be deformed. In addition, as the O-rings swell with time when immersed in salt water or caster oil, they could possibly expand sufficiently to force some members apart. Countering this is the fact that the durometer hardness measurement will increase as the seals are exposed to near freezing temperature at depth after assembly in possible hot sunshine.

f. General: It is imperative that the unit be 100% oil-filled prior to installation. This should effectively prevent any bending at the assembly ring if it is subjected to any bending moment during handling. It is not known if this is possible, since details of handling sheaves, etc. are not available. A brief investigation was made to ascertain if the shrinkage of the caster oil from deck conditions to installed conditions near 33°F could present any problems. No such problems are apparent.

A. W. McNairy

A. W. MCNAIRY

Copy to:
FPO-1HF
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Daily

| CHESAPEAKE DIVISION<br>Naval Facilities Engineering Command NDW<br>DISCIPLINE | PROJECT: BSURE CABLE TERMINATION<br>Station: ______<br>E S R: ______ Contract: ______ |
|---|---|
| Calcs made by: A.W. McNAIRY date: 12-8-81<br>Calcs ck'd by: ______ date: ______ | Calculations for: TOLERANCE STUDY RELATED TO SEALS |

NOTE: ALL CALLOUT NUMBERS REFER TO NUMBERS ON INTERIM "ASSEMBLY" DRAWING INCLUDED AT THE END OF THESE CALCULATIONS.

1) CHECK MORRISON SEAL, CALLOUT NO. 30, FOR INTERFERENCE UNDER WORST TOLERANCE CONDITIONS:

ASSUME (INITIALLY) THAT THE ~~.36~~ .37 ± .02 SEAL LENGTH DOES NOT CHANGE WHEN STRETCHED OVER THE .275 - .276 DIA. MANDREL FOR MEASURING SEAL THICKNESS.

SEAL O.D. ~~(MIN)~~ max (ON MANDREL) = ~~.275~~ .276 + (2)(~~.118~~ .135)

= ~~.511~~ .546 IN

SEAL O.D. ~~(MAX)~~ MIN (ON MANDREL) = ~~.276~~ .275 + (2)(.125)

= ~~.526~~ .525 IN.

CROSS SECTION AREA (MAX) = $\frac{1}{4}\pi[(.526)^2 - (.276)^2]$

= ~~.157 in~~ .174 in$^2$

∴ RELAXED DIA (MAX)

$\cancel{.157}\ .174 = \frac{1}{4}\pi[D^2 - (.260)^2]$

D = ~~.512~~ .540



(NOTE: The Delco Tolerance analysis included in COMPMTC LTR 3143, 2012 SERL 475 of 4 MAR 82 should be shown here also as it was the final tolerance analysis used.)

| | |
|---|---|
| **CHESAPEAKE DIVISION** Naval Facilities Engineering Command NDW DISCIPLINE | PROJECT: BSURF CABLE TERMINATION Station: ESR: Contract: |
| Calcs made by: A. W. McNAIRY date: 12-9-81 Calcs ck'd by: date: | Calculations for: TOLERANCE STUDY RELATED TO SEALS |

WHEN SEAL IS STRETCHED OVER THE .275 – .276 IN. DIA. MANDREL, IT RECEIVES A $\frac{.276}{\cancel{.260}\ .265} \approx \cancel{6.15\%}$ 4.2% CIRCUMFERENTIAL STRETCH, REDUCING THE ~~.38~~ .39 (MAX) LENGTH TO (EST.) ~~.357~~ .374 IN.

CHECK SEAL LENGTH WHEN INSTALLED OVER SHAFT #37 AND COMPRESSED INTO THE CAVITY OF THE SPOOL #32:

SEAL CROSS SECTION AREA $\approx$ ~~.157~~ .174 IN.$^2$

SHAFT (#37) AREA $= (.7854)(.288)^2$

$= .0651$ IN.$^2$ (MAX)

AND, $= (.7854)(.285)^2$

$= .0638$ IN.$^2$ (MIN)

$\therefore$ CONTAINED AREA $= .1963 - .0638 = .1325$ IN.$^2$ (MAX)

AND $= .1948 - .0651 = .1297$ IN.$^2$ (MIN)

$\therefore$ SEAL COMPRESSION $\approx \frac{(157)(100)}{.1325} = \cancel{18.49\%}$ 31% (MIN)

AND $\approx \frac{(.157)(100)}{.1295} = 21.24\%$ (MAX)

$\therefore$ INSTALLED SEAL LENGTH (MAX) $= (1.2124)(.357) = \cancel{.433}$ .480

| CHESAPEAKE DIVISION<br>Naval Facilities Engineering Command NDW<br>DISCIPLINE | PROJECT: BSURE CABLE TERMINATION<br>Station: ________<br>E S R: ________ Contract: ________ |
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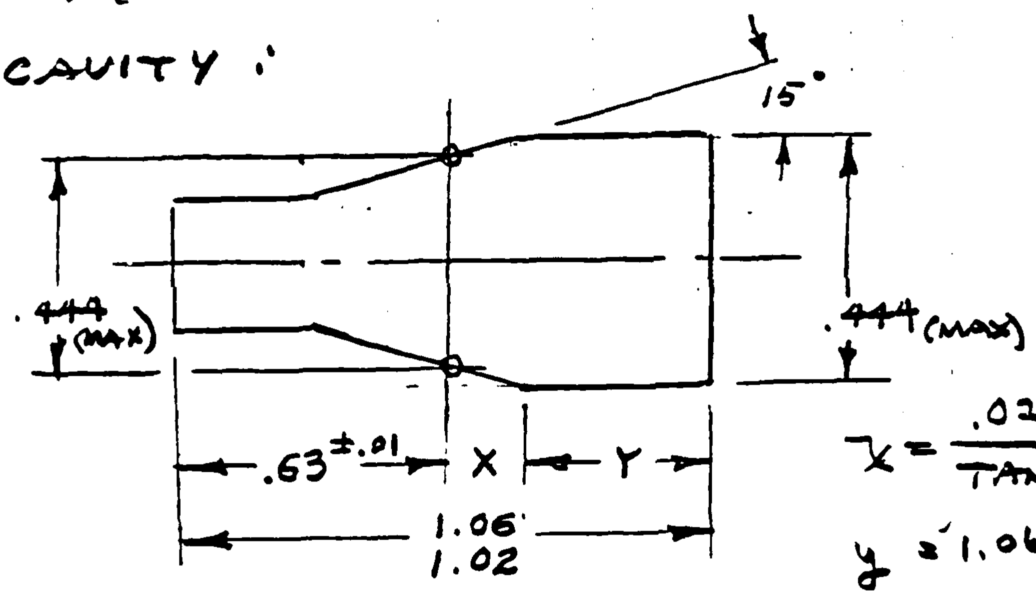
| Calcs made by: A. McNAIRY date: 12-9-81<br>Calcs ck'd by: ________ date: ________ | Calculations for: TOLERANCE STUDY RELATED TO SEALS |

CHECK VOLUME AVAILABLE FOR SEAL #30 WHEN CERAMIC INSULATOR, DWG. #7556495 IN PLACE. THE CAVITY IN PC. #32 IS .88 ± .01 LONG. THE CERAMIC INSULATOR CAN EXTEND THE FOLLOWING INTO THIS CAVITY:

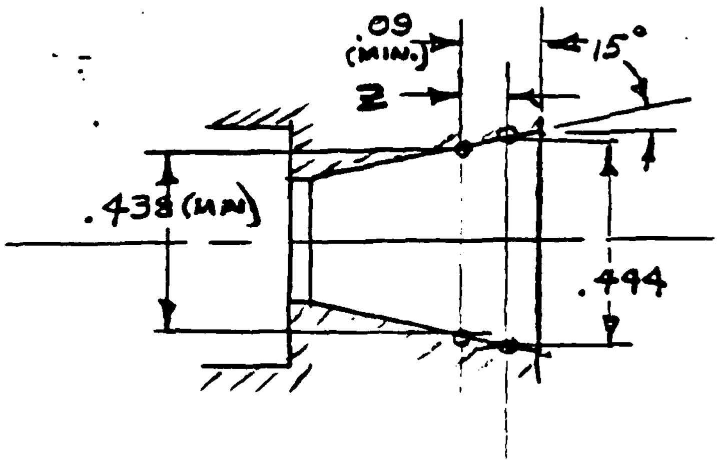



$$\begin{array}{r} .497 \\ -.444 \\ \hline \tfrac{1}{2}(.053 \\ \cancel{.0625} \\ .0265 \end{array}$$

$$x = \frac{.0265}{\tan 15^\circ} = .0989$$

$$y = 1.06 - \cancel{.62}\ .63 - .0989 = \cancel{.3411}\ .3311$$

TAPER NUT, PC. #27




$$Z = \frac{.5(.444 - .438)}{\tan 15^\circ}$$

$$= .0112$$

∴ MAX EXTENSION =

$$= .0112 + .0989 + \cancel{.3411}\ .3311$$

$$= \cancel{.4512}\ .4412 \text{ IN.}$$



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| | |
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| Calcs made by: A. McNAIRY date: 12-9-81<br>Calcs ck'd by: ____ date: ____ | Calculations for: TOLERANCE STUDY RELATED TO SEALS |

∴ MIN. CAVITY LENGTH = .87 − .4512 = .4188
(ASSUMING NO TEMP. OR PERMANENT DEFORMATION OF METAL IN TAPER)

∴ CAVITY VOLUME = (.1297)(.4188) = .054318 $in.^3$ (MIN)

SEAL VOLUME (MAX) = (.357)(.157) = .05605
— OR 3.2% MORE THAN AVAILABLE VOL.

OR, CHECKING LENGTHS, INSTALLED SEAL LENGTH IS .433 VS .4188 AVAIL. VOL. LENGTH
Clearance of 0.0288 in.
∴ ~~THERE CAN BE A GAP OF .0142~~ BETWEEN PC. #27 AND PC. #32, THIS GAP COULD BE GREATER, IF THERE IS SOME METAL COMPRESSION IN THE TAPER JOINTS AND IF THE .38 IN. LENGTH OF THE SEAL IS MEASURED WHILE IT IS ON THE .275-.276 IN. DIA. MANDREL. THE LATTER IS NOT CLEAR FROM THE DRAWING. IT ALONE COULD CAUSE A GAP OF .0419, SO WITH SOME MINOR METAL COMPRESSION IN THE TAPER, THE GAP COULD BE OVER .05 IN. WITH WORST-ON WORSE TOLERANCES — WHICH IS NOT LIKELY.

| | |
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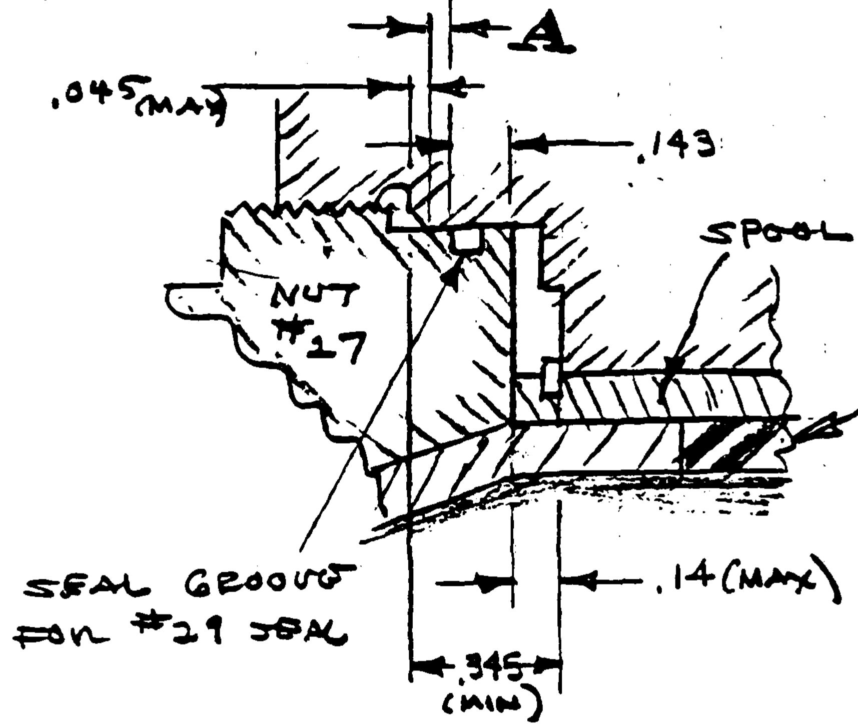
| **CHESAPEAKE DIVISION** Naval Facilities Engineering Command NDW DISCIPLINE | PROJECT: BSURE CABLE TERMINATION Station: ______ |
| | E S R: ______ Contract: ______ |
| Calcs made by: A. McNAIRY date: 12-9-81 | Calculations for: TOLERANCE STUDY |
| Calcs ck'd by: ______ date: ______ | RELATED TO SEALS |

1) CHECK EFFECT OF PIECE #27 BEING BACKED-OUT AS A RESULT OF THE POTENTIAL PROBLEM FROM PRECEDING PARAGRAPH.




∴ CLEARANCE A BETWEEN O-RING GROOVE AND EDGE, WITH SPOOL #32 BOTTOMED ON NUT #27:

$$A = .345 - .045 - .14 - .143 = \cancel{.017}\ .001 \text{ IN.}$$

SO, THERE IS ONLY MARGINAL CLEARANCE WITH PIECES #32 AND #27 BOTTOMED. THE



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| CHESAPEAKE DIVISION<br>Naval Facilities Engineering Command NDW<br>DISCIPLINE | PROJECT: BSURE CABLE TERMINATION<br>Station:<br>E S R: Contract: |
|---|---|
| Calcs made by: G. McNAIRY date: 12-9-81<br>Calcs ck'd by: date: | Calculations for: TOLERANCE STUDY RELATED TO SEALS, |

SEAL WILL BE EXPOSED AND INEFFECTIVE IF THERE IS ANY GAP OF .017 OR MORE. THUS, IT WOULD APPEAR THAT THE PRESENT SEAL, WHICH COULD CAUSE A GAP OF AT LEAST .014, AND POSSIBLY UP TO .05 OR MORE IS MARGINAL AT BEST, AND POSSIBLY UNSATISFACTORY. A REDUCTION IN SEAL #30 SIZE, POSSIBLY WIDTH, FROM .36 TO .30 WOULD SEEM IN ORDER.

IN ANY CASE, THE ASSEMBLY PROCEDURE SHOULD INCLUDE A POSITIVE INDICATION THAT NUT #27 IS BOTTOMED ON SPOOL #32.

3) CHECK SEAL #26 INSTALLATION (DWG # 7564138 REV A)

CHECK STRETCH, COMPRESSION :

RIGHT END (AS SHOWN ON INTERIM "ASSEMBLY DRAWING") - INSULATOR O.D. = .290 ± .005

CAVITY IN NUT = $\frac{.500}{.499}$ I.D.

| CHESAPEAKE DIVISION | PROJECT: BSURE CABLE TERMINATION |
|---|---|
| Naval Facilities Engineering Command NDW | Station: |
| DISCIPLINE | E S R: Contract: |
| Calcs made by: A. McNALRY date: 12-9-81 | Calculations for: TOLERANCE STUDY RELATED TO SEALS |
| Calcs ck'd by: date: | |

∴ SEAL I.D. OF .27 ± .01 MUST STRETCH A MINIMUM OF .005 IN. ON DIA., AND A MAXIMUM OF .035 IN. ON DIA. — O.K.

THE SEAL O.D. OF $^{.52}_{.51}$ (MEASURED WHEN ON MANDREL EQUIVALENT TO ACTUAL INSTAL.) MUST COMPRESS INTO CAVITY OF NUT $^{.500}_{.499}$ O.K.

CHECK AVAILABLE VOLUME (MIN) VS SEAL VOLUME (MAX.):

| | |
|---|---|
| CAVITY LENGTH (NUT-PC #27) - | .275 |
| ISOLATION TUBE -(PC #27) - | .455 |
| | .730 |
| CENTER CONTACT - | - .115 |
| ∴ CAVITY LENGTH (MIN) = | .615 |
| CAVITY O.D. (MIN) = | .499 |

INSULATOR LENGTH:

FOR MAX. TOLERANCE ON NUT AND INSULATOR, DISTANCE INTO CAVITY (LEFT ON ASS'Y DW'G) FROM MEASURING POINT IS AS FOLLOWS:



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| | |
|---|---|
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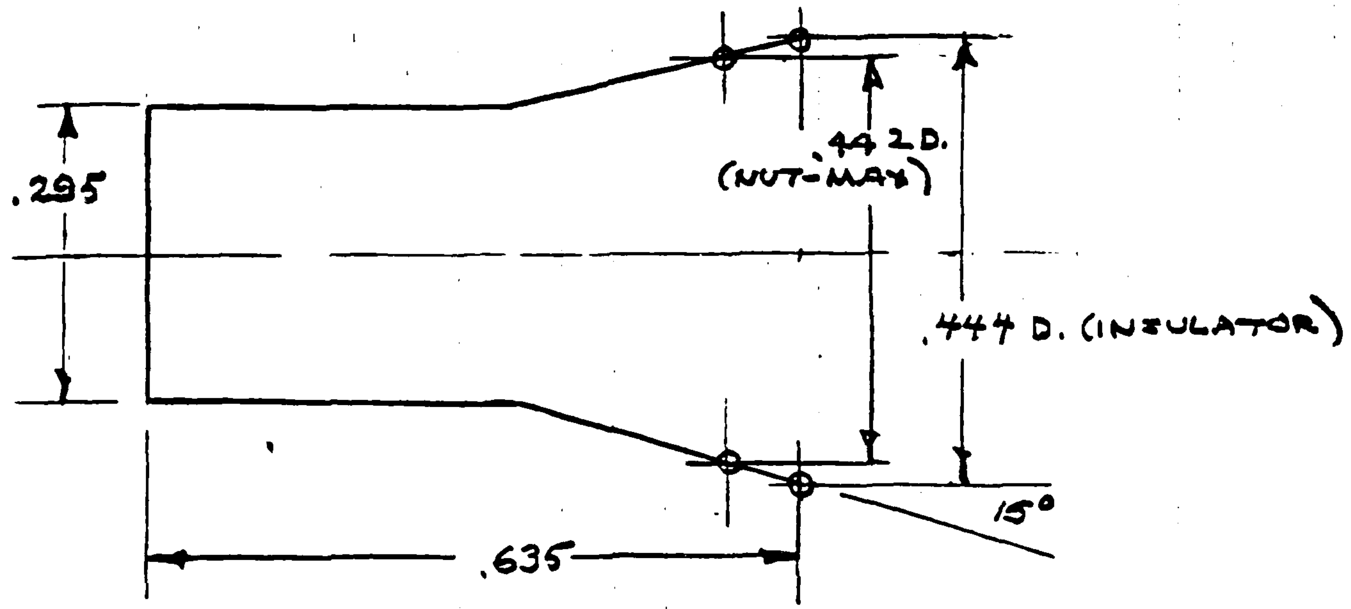
| Calcs made by: A. W. McNAIRY date: 12-9-81<br>Calcs ck'd by: date: | Calculations for: TOLERANCE STUDY RELATED TO SEALS |




DIST. FROM MEAS. POINT (NUT) TO PARALLEL SECTION OF INSULATOR = $\frac{.2210-.1475}{TAN\ 15°}$ = .2743

DIST. FROM MEAS. PT. (NUT) TO MEAS. POINT (INSULATOR) = $\frac{.001}{TAN\ 15°}$ = .0037

∴ DIST. FROM MEASURING POINT (NUT) TO PARALLEL SECTION OF INSULATOR = .2743+.0037 = .278

DIST. FROM MEAS. PT. (NUT) TO INNER CAVITY (SEAL-MAX) = .610-.100-.280 = .280

∴ ONLY CYLINDRICAL PORTION OF INSULATOR IS IN CAVITY – A LENGTH OF .64-.278 = .362 IN.



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| CHESAPEAKE DIVISION | PROJECT: BSURE CABLE TERMINATION |
|---|---|
| Naval Facilities Engineering Command NDW | Station: |
| DISCIPLINE | E S R: Contract: |
| Calcs made by: A.W. McNAIRY date: 12-11-81 | Calculations for: TOLERANCE STUDY RELATED TO SEALS |
| Calcs ck'd by: date: | |

$\therefore$ CAVITY VOLUME $= \frac{\pi}{4}\left[(.615)(.499)^2-(.362)(.295)^2-(.253)(.166)^2\right]$

$= .0901 \text{ in.}^3$

SEAL VOL. $= \frac{\pi}{4}\left[(.49)(.52)^2-(.17)(.142)^2-(.32)(.26)^2\right]$

$= .0843 \text{ in.}^3$

O.K. – THIS IS 93.57 % OF AVAIL. VOL.

IF BACK-UP SEAL RING, DW'G. NO. 7564009, IS USED, ~~SEAL~~ (BACK-UP) VOL $= \frac{\pi}{4}(.065)\left[(.498)^2-(.286)^2\right]$

$V = .0085 \text{ in.}^3$, OR TOTAL VOL $= .0928 \text{ in.}^3$

THIS IS 3% MORE THAN CAVITY VOLUME, SO A SMALL AMOUNT OF GAPPING COULD OCCUR.

4) CHECK MORRISON SEALS NOS. 14 AND 20: FIRST, CHECK MINIMUM LENGTH OF SPACE FOR SEAL #20:

ASSUME CABLE TERMINATOR, PIECE NO. #18, BUTTS FIRMLY INTO SOCKET OF FEMALE



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| CHESAPEAKE DIVISION<br>Naval Facilities Engineering Command NDW<br>DISCIPLINE | PROJECT: BSURE CABLE TERMINATION<br>Station:<br>E S R: Contract: |
|---|---|
| Calcs made by: A.W. McNAIRY date: 12-16-81<br>Calcs ck'd by: date: | Calculations for: TOLERANCE STUDY RELATED TO SEALS |

CENTER CONTACT - DWG NO. 756414O.

IF SO, CAVITY LENGTH (MIN) = .385 IN.

CAVITY DIA. (MIN.) = .685 IN.

ASSUME (?) POTTED STRENGTH MEMBER OF CABLE TERMINATE PRECISELY AT START OF TAPER (.385 IN FROM END.)

∴ MIN. VOL. AVAILABLE FOR TWO SEALS IS $(.7854)(.685)^2(.385) = .142 \text{ in}^3$

NOW, MAX. SEAL VOL;

SEAL #20 (7563620) = -.001 $= (.7854)(.72)^2(.32)$

$= .130 \text{ in}^3$

SEAL # 7563962 $= (.7854)(.680)^2(.045)$

$= .016$

∴ TOTAL VOL = $.146 \text{ in}^3$

SO SEAL WOULD EXTEND $\dfrac{.146 - .142}{(.7854)(.634)^2}$

$= .013$ in.

INTO TAPER - THIS MAY OR MAY NOT (PROBABLY NOT) BE AN ISSUE, SINCE ASSUMPTION OF EXACT LOCATION OF END OF POTTING



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IS UNKNOWN.

CHECK SEAL #14 INSTALLATION:

ASSUME (FOR NOW --) THAT COMPRESSION NUT, DWG #7563617 IS BOTTOMED INTO STRENGTH CABLE TERMINATION, DWG #7564144 (ITEM NO. 18) –

MAX. ENTRY IS: .670 − .120 − .300 = .250

MIN. CAVITY LENGTH = .620 (PC. 7564144)

∴ MIN CAVITY LENGTH FOR SEAL =

.620 − .250 = .370 IN.

MIN. CAVITY DIA. = .700 IN

MAX. CABLE DIA = .331 IN.

$\therefore$ MIN. VOL. FOR SEAL $= .7854\left[(.700)^2-(.331)^2\right].370$

$= .111\ \text{in.}^3$

MAX SEAL VOL = ~~(.34)(.3245~~

$= (.34)\left[(.7445)^2-(.3245)^2\right](.7854)$

$= .120\ \text{in.}^3$

∴ COMPRESSION NUT IS NOT BOTTOMED, BUT CAN BE BACKED OFF (GAP):

$\text{DIST.} = \dfrac{.120-.111}{.7854\left[(.700)^2-(.331)^2\right]} = .030\ \text{IN.}$

**CHESAPEAKE DIVISION**
Naval Facilities Engineering Command NDW
DISCIPLINE
Calcs made by: A. McNAIRY date: 12-2-81
Calcs ck'd by: ________ date: ________

PROJECT: BSURE CABLE TERMINATION
Station: ________
E S R: ________ Contract: ________
Calculations for: TOLERANCE STUDY RELATED TO SEALS

CHECK ASSEMBLY OF STRENGTH TERMINATOR AND SURROUNDING COMPONENTS:

MIN. LENGTH OF STRENGTH TERMINATOR SUPPORT TUBE, DWG #756449 = 3.195

MAX. LENGTH = 3.205

MIN. LENGTH OF TERMINATOR LOCK NUT, DWG #756445 = .375

MAX. LENGTH = .385

COMBINED LENGTHS OF THESE:

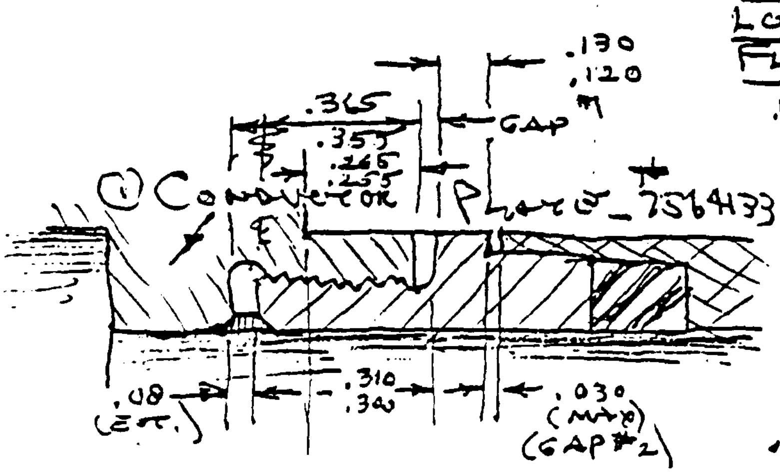
MIN. = 3.570 IN.

MAX = 3.590 IN.

NOW, CHECK COMPONENTS ASSEMBLED WITHIN THESE TWO ITEMS:

DISTANCE FROM LOAD-BEARING PLATE FLAT SURFACE

| MAX. | MIN. |
| --- | --- |
| .265 | .255 |



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| CHESAPEAKE DIVISION<br>Naval Facilities Engineering Command NDW<br>DISCIPLINE | PROJECT: BSURE CABLE TERMINATION<br>Station:<br>E S R: Contract: |
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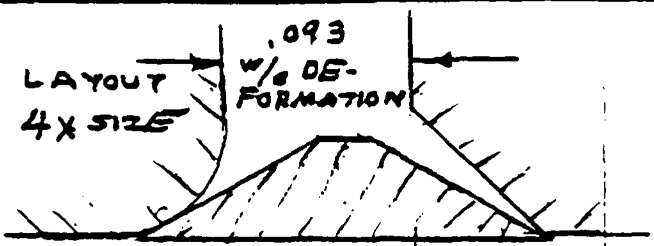
| Calcs made by: A. McNAIRY date: 12-3-81<br>Calcs ck'd by: date: | Calculations for: TOLERANCE STUDY RELATED TO SEALS |




ESTIMATE .080 WITH DEFORMATION (?) –

∴ GAP #1 = .300 + .08 – .365

= .015 IN. (MIN) →

= .310 + .08 – .355

= .035 IN. (MAX) →

| | | |
|---|---|---|
| | .035 | .015 |
| COMPRESSION NUT FLANGE | .130 | .120 |
| GAP #2 | .030 | .000 (EST.) |
| STRENGTH TERMINATOR | 3.485 | 3.475 |
| TOTALS | 3.945 | 3.865 |

∴ COMPONENTS EXTEND : 3.865 – 3.590

= .275 IN. (MIN)

AND 3.945 – 3.570

= .375 IN. (MAX)

THE CAVITY IN #7564140, FEMALE CENTER CONTACT IS ~~.375~~ .385 DEEP

∴ THERE IS A GAP OF .11 IN. (MAX)

| | |
|---|---|
| **CHESAPEAKE DIVISION**<br>Naval Facilities Engineering Command NDW<br>DISCIPLINE | PROJECT: BSURE CABLE TERMINATION<br>Station: ____<br>E S R: ____ Contract: ____ |
| Calcs made by: A. McNAIRY date: 12-3-81<br>Calcs ck'd by: ____ date: ____ | Calculations for: TOLERANCE STUDY RELATED TO SEALS. |

AND .000 IN. (MIN.). THUS GAP DOES NOT APPEAR GREAT ENOUGH TO USE THE 756362-002 SEAL WHICH HAS A THICKNESS OF .80, RATHER THAN .31 _ ITS USE IS UNKNOWN ——— .

Not USED IN The BSURE Cable Termination IT is USED IN The UCS Retrieval Cable

5) CHECK VOLUME OF SEALS #1 & #2 (MORRISON SEALS) RELATIVE TO AVAIL. VOL:

SEAL VOL. (MAX) $= (.77)(.7854)\left[(2.690)^2-(.880)^2\right]$

$= 3.911 \text{ in}^3$

$\therefore$ TOTAL (2) SEAL VOL. $= 7.822 \text{ in}^3$

CABLE DIA. (MAX.) = .905"

TERMINATION HOUSING (PC #9) I.D. (MIN.) = 2.598"

LENGTH OF CAVITY (MIN):



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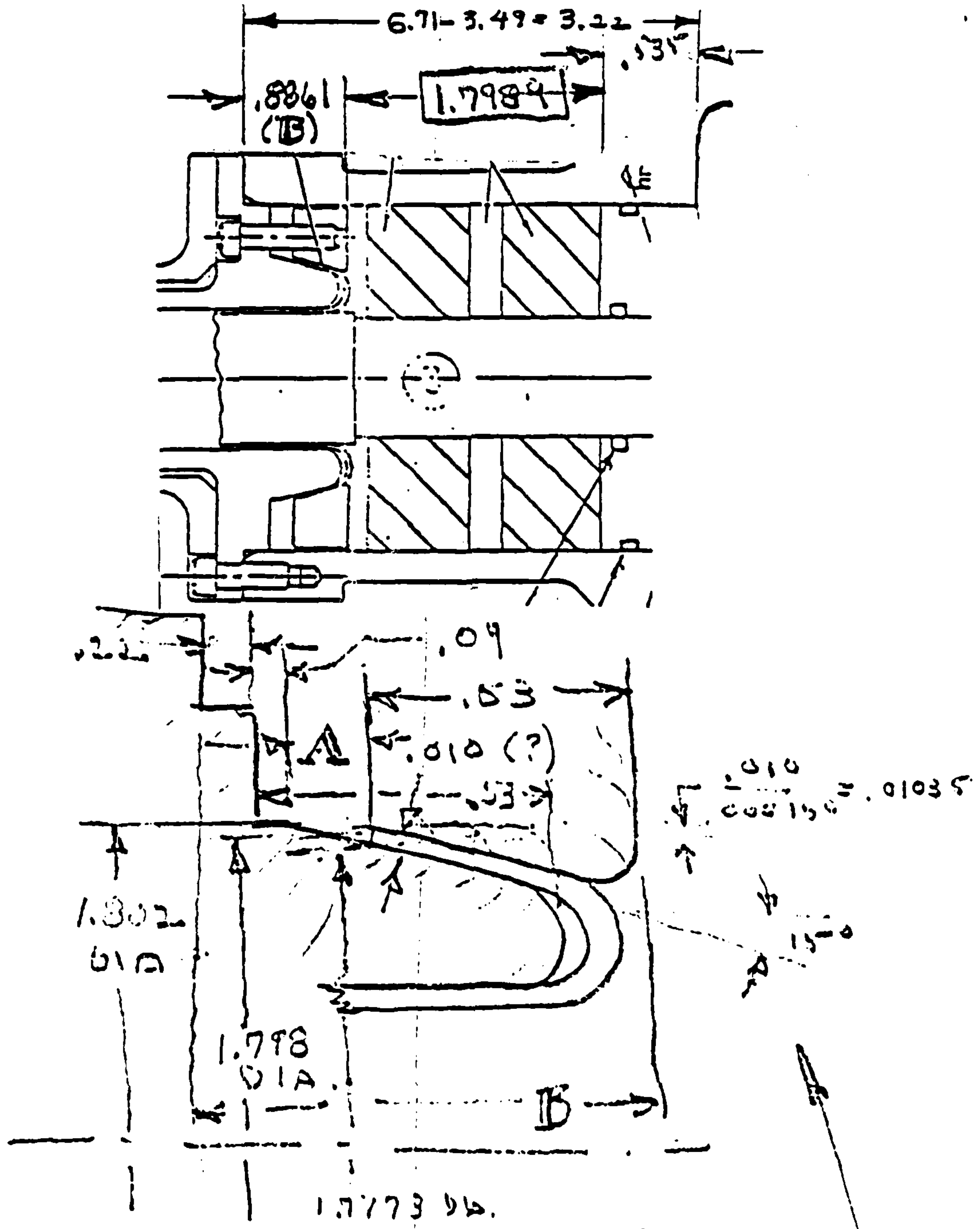
|---|---|
| Calcs made by: A. McNAIRY date: 12-1-81<br>Calcs ck'd by: ______ date: ______ | Calculations for: TOLERANCE STUDY RELATED TO SEALS |




$\therefore$ DIST. A $= \dfrac{.5(1.802 - 1.7773)}{\tan 15°} = .0461$

$\therefore$ DIST B $= .22 + .09 + .0461 + .53 = .8861$ page 15 of 29

| CHESAPEAKE DIVISION<br>Naval Facilities Engineering Command NDW<br>DISCIPLINE | PROJECT: BSURE CABLE TERMINATION<br>Station: ______<br>E S R: ______ Contract: ______ |
|---|---|
| Calcs made by: A. McNAIRY date: ______<br>Calcs ck'd by: ______ date: ______ | Calculations for: TOLERANCE STUDY RELATED TO SEALS |

AVAILABLE VOL. $\approx (1.7989)(.7854)\left[(2.598)^2-(.905)^2\right]$
$= 8.379 \text{ in}^3$

THIS IS 7.12% MORE THAN REQ.
FOR SEALS. O.K.

MAX. LINEAR GAP WOULD BE:

$$\frac{8.379 - 7.822}{(.7854)\left[(2.598)^2-(.905)^2\right]} = .1195$$

—OR APPROX 1/8 INCH — — —O.K.

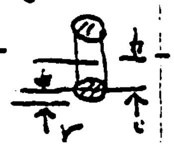
6) CHECK OF O-RINGS NOS. 33 & 34, WITH UP-DATED DRAWING OF PIECE NO. 32 — DWG NO. 7564121, DATED 9-30-80
- NOTE: — O-RING GROOVES (VIEW A-A) HAVE BEEN CHANGED, ALSO O-RINGS, FROM OLDER DWG, DIAM. CL. OF BOTH GROOVES IS NOW .197 MIN, .209 MAX & RADIAL CL. ≈ .0985 MIN, .1045 MAX
FROM LIST "10-CONNECTOR WITH CABLES" O-RINGS NOS. 33 AND 34 ARE NOW THE SAME (AS ARE THE GROOVES) → M83248/1-205

| CHESAPEAKE DIVISION<br>Naval Facilities Engineering Command NDW<br>DISCIPLINE | PROJECT: BSURE CABLE TERMINATION<br>Station: ______<br>E S R: ______ Contract: ______ |
|---|---|
| Calcs made by: A. McNAIRY date: ______<br>Calcs ck'd by: ______ date: ______ | Calculations for: TOLERANCE STUDY RELATED TO SEALS |

NOW I.D. = .421 ± .005

ASSUME, FOR <u>MIN.</u> COMPRESSION, THAT MAX I.D. IS STRETCHED TO MIN. GROOVE O.D., .426 TO .488

A. TORUS (O-RING) VOL = $2\pi^2 c r^2$

WHERE  $r_1$ (MIN) = .139 − .004

$\therefore r_2 = r_1\sqrt{\frac{c_1}{c_2}} = .135\sqrt{\frac{.426}{.488}} = .126$

$d_2 = d_1\sqrt{\frac{2c_1}{2c_2}}$ → (USING DIAMETERS)

$\therefore$ COMPRESSION (MIN) $= \frac{.126}{.1045} = 1.2057$

− OR 20.57% − WHICH IS RIGHT IN THE MIDDLE OF STATIC O-RING COMPRESSION OF 17 TO 24% RECOMMENDATION.

NOW, CHECK ~~MAX.~~ MIN. COMPRESSION; USING MIN. O.RING I.D. = .421 − .005 = .416 AND MIN. GROOVE O.D. − OR .416 TO .488

$\therefore d_2 = .135\sqrt{\frac{.416}{.488}} = .1246$

$\therefore$ COMPRESSION $= \frac{.1246}{.1045} = 1.1928$

OR 19.28% − O.K.

| CHESAPEAKE DIVISION Naval Facilities Engineering Command NDW DISCIPLINE | PROJECT: BSURE CABLE TERMINATION Station: |
|---|---|
| Calcs made by: A. McNAIEY date: | E S R: Contract: |
| Calcs ck'd by: date: | Calculations for: TOLERANCE STUDY RELATED TO SEALS |

NOW, FOR MAX. COMPRESSION:
USE MAX. GROOVE DIA., & MAX.
O-RING I.DIA. & MIN. HOUSING DIA. &
MAX. O-RING X-SECTION O.D.

MAX GROOVE DIA = .490

MIN. HOUSING DIA = .687

MAX O.RING I.D. = .426

MAX O-RING X-SECTION DIA. = .139+.004

$\therefore d_2 = .143\sqrt{\frac{.426}{.490}} = .133$

$\therefore$ COMPRESSION $= \frac{.133}{.0985} = 1.350$

OR 35.0% — OR 46% MORE THAN RECOMMENDED MAX,

THIS MAY BE HIGH, SINCE O-RING X-SECTION WILL PROBABLY BE MORE OF AN ELLIPSE THAN A CIRCLE, HENCE LOWER COMPRESSION. IF 35% COMPRESSION RESULTS IN 35% WIDTH INCREASE (?), THEN O-RING WIDTH (UNRESTRAINED), WOULD BE (1.35)(.143) = .193 IN. THE

| | |
|---|---|
| **CHESAPEAKE DIVISION**<br>Naval Facilities Engineering Command NDW<br>DISCIPLINE | PROJECT: BSURE CABLE TERMINATION<br>Station:<br>E S R: Contract: |
| Calcs made by: A. McNAIRY date:<br>Calcs ck'd by: date: | Calculations for: TOLERANCE STUDY RELATING TO SEALS |

O-RING GROOVE MIN. IS .235 IN. O.K.
BUT, ARE THERE ANY BACK-UP
RINGS USED? _ NONE ON THE
LIST, BUT AT THESE (7500 PSI) PRESSURES
ONE WOULD CERTAINLY EXPECT THEM---
TWO DWG'S SHOW SEALING WASHERS
- DWG NO. 756400B - .498 O.D., .287 I.D.
t = .065, & NO. 756276., .749 O.D., .250 I.D.
t = .06 - NEITHER WOULD FIT WITH
THESE O-RINGS, WITHOUT AN ASS'Y
DWG, THESE CANNOT BE LOCATED
EASILY.

No

Wrong drawing See page 9

7) CHECK FIT OF PC. #27 & O-RING INTO
HOUSING, PC #21 → 1.373 (MAX) INTO 1.375 (MIN)
— O.K.
O-RING GROOVE DIA = 1.275 (MAX), 1.273 (MIN)
HOUSING (PC #21) I.D. = 1.376 (MAX), 1.375 (MIN)
∴ DIAMETRAL CL. = .103 (MAX), .100 (MIN)
RADIAL CL. = .0515 (MAX), .0500 (MIN)
O-RING, PC. #29 IS M 83248/1-026
HAS NOM. I.D. OF 1.239 ± .066



GPO 942-951

| CHESAPEAKE DIVISION | PROJECT: BSURE CABLE TERMINATION |
|---|---|
| Naval Facilities Engineering Command NDW | Station: |
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| Calcs made by: A. McNAIRY date: | Calculations for: TOLERANCE STUDY RELATING TO SEALS |
| Calcs ck'd by: date: | |

∴ FOR MAX COMPRESSION, THIS 1.233 DIA STRETCHES TO 1.275 DIA.

∴ O-RING DIA DECREASES FROM .073

TO $.073\sqrt{\frac{1.233}{1.275}} = .0718$

∴ MAX COMPRESSION = $\frac{.0718}{.050} = 1.436$

OR 43.6 % COMPRESSION - THIS IS MUCH GREATER THAN NORMAL 24 % MAX FOR A STATIC O-RING ---

FOR MIN COMPRESSION, THE 1.245 (MAX) I.D. OF O-RING STRETCHES TO 1.273 (MIN) RING GROOVE I.D.

∴ O-RING CROSS SECTION (MIN) $= .067\sqrt{\frac{1.245}{1.273}}$

$= .0663$ DIA.

∴ MIN COMPRESSION = $\frac{.0663}{.0515} = 1.2866$

OR 28.66 % COMPRESSION - STILL APPRECIABLY GREATER THAN NORMAL MIN OF 17 % COMPRESSION ... BUT, IT IS ASSUMED THAT O-RING CROSS-SECTION BECOMES SOMEWHAT



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| CHESAPEAKE DIVISION<br>Naval Facilities Engineering Command NDW<br>DISCIPLINE | PROJECT: BSURE CABLE TERMINATION<br>Station:<br>E S R: Contract: |
| --- | --- |
| Calcs made by: A. McNAIRY date:<br>Calcs ck'd by: date: | Calculations for: TOLERANCE STUDY RELATING TO SEALS |

OF AN ELLIPSE WHEN STRETCHED

RATHER THAN CIRCULAR - SO

THESE NUMBERS WILL BE HIGH ---

CHECK O-RING GROOVE WIDTH

TO ACCOMMODATE MAX COMPRESSION:

GROOVE WIDTH (MIN) = .093

FOR THE 43.6% COMPRESSION, RING

WILL TEND TO MASH-OUT APPROX:

$(.0718)(1.436) = .103$ in., OR

10.87% MORE THAN GROOVE WIDTH.

CHECK AVAILABLE VOLUME:

O-RING CROSS-SECTION AREA $= .7854(.0718)^2$

$= .0040$ in.$^2$

O-RING GROOVE AREA $\approx (.050)(.093) = .00465$

$\therefore$ THERE IS ONLY A 16% SURPLUS AREA

AVAILABLE — SO RING MUST ASSUME

ALMOST A RECTANGULAR SHAPE ---

-BUT IT WILL, BARELY, GO IN.—

-WOULD SEEM TO PRESENT AN

INSTALLATION PROBLEM. - - - - -

Hasn't been a Problem in 75 assemblies

8) CHECK SEALS #12 & 13 (O-RINGS)

LOAD BEARING PLATE ASSY - ITEM #6

HAS $\begin{matrix}1.752\\1.750\end{matrix}$ I.D.

FEMALE ISOLATION TUBE, ITEM #22

HAS $\begin{matrix}1.748\\1.747\end{matrix}$ O.D. — O.K. CL. CAMAGE .005 MAX

O-RING GROOVE DIA. = $\begin{matrix}1.650\\1.648\end{matrix}$

THE O-RINGS, ITEMS #12 & 13 ARE

M 83248/1-030 — HAVE 1.614 I.D. ±.010

& W = .070 ±.003

FOR MAX COMPRESSION O-RING

STRETCHES FROM 1.624 TO 1.650

$\therefore$ O-RING DIA $\approx .073\sqrt{\frac{1.624}{1.650}} = .072$

$\therefore$ MAX. COMPRESSION $\approx \frac{.072}{.5(1.750-1.650)}$

$= 1.44$ OR 44% COMPR.

FOR MIN COMPRESSION - O-RING STRETCHES

FROM 1.604 DIA. TO 1.648

$\therefore$ O-RING DIA. $\approx .067\sqrt{\frac{1.604}{1.648}} = .066$

$\therefore$ MIN. COMPRESSION $\approx \frac{.066}{.5(1.752-1.648)} = 1.27$

OR 27% COMPRESSION



GPO 942-951

| | |
|---|---|
| **CHESAPEAKE DIVISION** Naval Facilities Engineering Command NDW DISCIPLINE | PROJECT: BSURE CABLE TERMINATION Station: |
| | E S R: Contract: |
| Calcs made by: A. McNAIRY date: | Calculations for: TOLERANCE STUDY RELATING TO SEALS |
| Calcs ck'd by: date: | |

THE O-RING GROOVES FOR MAX COMPRESSION ARE .093 X .05

FOR A X-SECTION AREA OF $.00465\ in^2$

THE O-RING AREA $= .7854(.072)^2 = .00407\ in^2$

– SO THERE IS ROOM – –

BUT 87.5% OF SPACE IS TAKEN –

SEEMS LIKE A REAL SQUEEZE & ASSEMBLY PROBLEM –

9) CHECK BAND-SEAL #19 AROUND ITEM #22

MIN. GROOVE DIA. = 2.20 IN.

ASSUME -002 SEAL (LARGER ONE)

MAX. I.D. = 1.86 → O.K.

GROOVE WIDTH = .360 MIN.

SEAL WIDTH = .36 MIN – O.K.

(WILL BE LESS WHEN STRETCHED)

10) CHECK BAND SEAL #21 – WRAPPED AROUND MALE ISOLATION TUBE – #25 :

MIN GROOVE DIA = 1.63 IN.



GPO 942-951

| | |
|---|---|
| CHESAPEAKE DIVISION<br>Naval Facilities Engineering Command NDW<br>DISCIPLINE | PROJECT: BSURE CABLE TERMINATION<br>Station:<br>E S R: Contract: |
| Calcs made by: A. McNAIRY date:<br>Calcs ck'd. by: date: | Calculations for: TOLERANCE STUDY RELATING TO SEALS |

ASSUME -001 SEAL (SMALLER ONE)

MAX I.D. = 1.34 → O.K.

GROOVE WIDTH = .37-.01 = .36 → O.K.

11) QUICK SEAL #23 & #24

O-RING GROOVE I.D. (PIECE #21) = $\begin{cases}1.900\\1.898\end{cases}$

FEMALE ISOLATION TUBE I.D. (#22) $\begin{cases}2.002\\2.000\end{cases}$

O-RING #23 & #24 - M 83248/1-032

I.D. (MIN) = $\begin{cases}1.874\\1.854\end{cases}$

W = $\begin{cases}.073\\.067\end{cases}$

FOR MAX. COMPRESSION, O-RING STRETCHES

FROM ~~1.900~~ 1.874 TO 1.900 DIA.

$\therefore$ O.RING DIA(W) = $.073\sqrt{\frac{1.874}{1.900}} = .0725$

$\therefore$ MAX COMPRESSION $\approx \frac{.0725}{.5(2.000-1.900)} = 1.45$

OR 45% COMPR.

FOR MIN COMPRESSION, O-RING STRETCHES

FROM ~~1.900~~ 1.854 TO 1.898

$\therefore$ O.RING DIA. = $.067\sqrt{\frac{1.854}{1.898}} = .0662$

$\therefore$ MIN COMPRESSION $\approx \frac{.0662}{.5(2.002-1.898)}$

$= 1.273$ — OR 27.3% COMP.

| CHESAPEAKE DIVISION | PROJECT: BSURE CABLE TERMINATION |
|---|---|
| Naval Facilities Engineering Command NDW | Station: |
| DISCIPLINE | E S R: Contract: |
| Calcs made by: A. McNAIRY date: | Calculations for: TOLERANCE STUDY |
| Calcs ck'd by: date: | RELATING TO SEALS |

12) CHECK SEAL ~~#15~~ & #16 -

O.RING GROOVE I.D. (PIECE #21) $\begin{cases} 3.528 \\ 3.526 \end{cases}$

TERMINATION HOUSING I.D. - $\begin{cases} 3.752 \\ 3.750 \end{cases}$

O-RING - MS 28775/1-238

I.D. = $\longrightarrow$ $\begin{cases} 3.499 \\ 3.469 \end{cases}$

W = $\longrightarrow$ $\begin{cases} .143 \\ .135 \end{cases}$

FOR MAX COMPRESSION, O-RING STRETCHES FROM 3.499 TO 3.528 DIA.

$\therefore$ O-RING DIA $\approx .143\sqrt{\frac{3.499}{3.528}} = .1424$ in.

$\therefore$ MAX COMPRESSION $= \frac{.1424}{.5(3.750-3.528)}$

$= 1.2828$, OR $\underline{28.28}$ %

FOR MIN COMPRESSION, O-RING STRETCHES FROM 3.469 TO 3.526 DIA.

$\therefore$ O-RING DIA $\approx .135\sqrt{\frac{3.469}{3.526}} = .1339$

$\therefore$ MIN COMPRESSION $\approx \frac{.1339}{.5(3.752-3.526)}$

$= 1.1849$ OR $\underline{18.49}$ %

COMPR.

THESE TWO SEALS ARE, TO SOME DEGREE, RECIPROCATING SEALS, AS COMPARED TO STATIC SEALS IN ALL

| CHESAPEAKE DIVISION<br>Naval Facilities Engineering Command NDW<br>DISCIPLINE | PROJECT: BSURE CABLE TERMINATION<br>Station:<br>E S R: Contract: |
|---|---|
| Calcs made by: A. McNAIRY date:<br>Calcs ck'd by: date: | Calculations for: TOLERANCE STUDY RELATING TO SEALS |

OTHER O-RING APPLICATIONS. DOES THIS 28.28% COMPRESSION (MAX) PRESENT A PROBLEM FOR SUCH AN APPLICATION? OR IS THERE ANY MOVEMENT OF #21 31 INTO #9? (DURING PRESSURIZATION DURING DESCENT?...) yes

AT MAX COMPRESSION, O-RING OCCUPIES 77.37% OF GROOVE

13) CHECK SEAL #5

O-RING GROOVE (PIECE #6) I.D. = $^{2.438}_{2.436}$

HOUSING TERMINATION I.D. (PIECE #9) $^{2.600}_{2.590}$

O-RING #5 - M 83248/-142

I.D. = ⟶ $^{2.372}_{2.352}$

W = ⟶ $^{.106}_{.100}$

FOR MAX. COMPRESSION O-RING (2.78%)

STRETCHED FROM 2.~~438~~ 372 DIA. TO 2.438 DIA.

$\therefore$ O-RING DIA (W) $\simeq .106\sqrt{\frac{2.372}{2.438}} = .1046$

$\therefore$ MAX COMPRESSION $\simeq \frac{.1046}{.5(2.590-2.438)}$

$= 1.3763$ OR 37.63%

FOR MIN. COMPRESSION, O-RING (3.57%)



GPO 942-951

| | |
|---|---|
| **CHESAPEAKE DIVISION** Naval Facilities Engineering Command NDW | PROJECT: BSURE CABLE TERMINATION |
| DISCIPLINE | Station: |
| | E S R: Contract: |
| Calcs made by: A. McNairy date: | Calculations for: TOLERANCE STUDY RELATING TO SEALS |
| Calcs ck'd by: date: | |

STRETCHES FROM 2.352 DIA. TO 2.436 DIA.

$\therefore$ O-RING DIA. $\approx .100\sqrt{\frac{\cancel{2.436}\ 2.352}{2.436}}$

$= .0983$ in

$\therefore$ COMPRESSION (MIN) $\approx \frac{.0983}{.5(\cancel{2.600}\ \cancel{2.436}\ 2.600 - 2.436)}$

$= 1.1988$, or 19.88 % COMPS

14) CHECK SEALS #4 & #7

O-RING GROOVE (PIECE #6) O.D. $\begin{cases} 1.062 \\ 1.060 \end{cases}$

CABLE O.D. ⟶ $\begin{cases} .905 \\ .900 \end{cases}$

O-RING #4 & #7 - M83248/1-118

I.D. = $\begin{matrix} .868 \\ .856 \end{matrix}$, W = $\begin{matrix} .106 \\ .100 \end{matrix}$

FOR MAX. COMPRESSION, O-RING

STRETCHES FROM .868 DIA TO .905 DIA.

$\therefore$ O-RING DIA. (W) $\approx .106\sqrt{\frac{.868}{.905}} \approx .1038$ in.

$\therefore$ MAX COMPRESSION $= \frac{.1038}{.5(1.060 - .900)}$

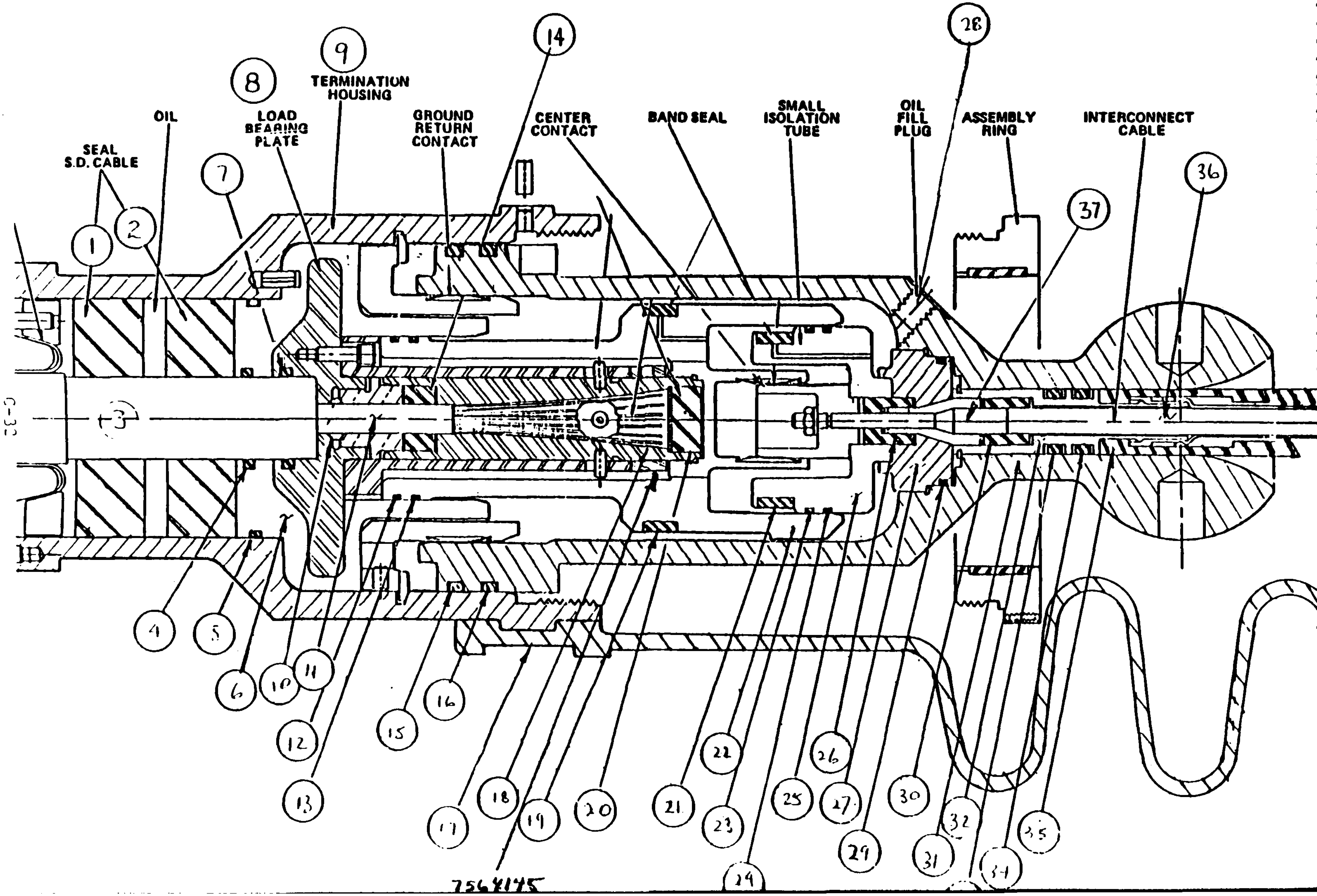
$= 1.3394$ OR 33.94 %

FOR MIN COMPRESSION, O-RING STRETCHES

FROM .856 TO .900

$\therefore$ O-RING DIA. (W) $\approx .100\sqrt{\frac{.856}{.900}} = .0975$ in.

$\therefore$ MIN. COMPRESSION $= \frac{.0975}{.5(1.062 - .900)} = 1.2037$ OR 20.37 %


SEAL S.D. CABLE
OIL
LOAD BEARING PLATE
TERMINATION HOUSING
GROUND RETURN CONTACT
CENTER CONTACT
BAND SEAL
SMALL ISOLATION TUBE
OIL FILL PLUG
ASSEMBLY RING
INTERCONNECT CABLE
7564145

# 10 - CONNECTOR WITH CABLES

| BLOCK DIAGRAM NUMBER | DELCO DRAWING NUMBER | NOMENCLATURE | SKETCH NUMBER |
|---|---|---|---|
| 10.01 | 7564122 | HOUSING - TERMINATION | 9 |
| 10.02 | 7563536 | SEAL, CABLE SHEATH | 1 |
| 10.03 | 7563758 | SD CABLE, INNER POLYETHYLENE | 3 |
| 10.04 | 7563758 | SD CABLE. OUTER POLYETHYLENE | 3 |
| 10.05 | BLANK | — | — |
| 10.06 | 7563758 | SD CABLE. INNER COPPER JACKET | 11 |
| 10.07 | 7564139 | SEAL, CABLE SHEATH | 2 |
| 10.08 | M83248/1-142 | PACKING. PREFORMED | 5 |
| 10.09 | 7564131 | LOAD BEARING PLATE | 6 |
| 10.10 | M83248/1-118 | PACKING, PREFORMED | 4 |
| 10.11 | M83248/1-030 | PACKING, PREFORMED | 12 |
| 10.12 | M83248/1-030 | PACKING, PREFORMED | 13 |
| 10.13 | 7564142-001 | BAND SEAL | 19 |
| 10.14 | 7564142-002 | BAND SEAL | 21 |
| 10.15 | 7564147 | FEMALE ISOLATION TUBE | 22 |
| 10.16 | M83248/1-032 | PACKING PREFORMED | 23 |
| 10.17 | M83248/1-032 | PACKING PREFORMED | 24 |
| 10.18 | 7564146 | MALE ISOLATION TUBE | 25 |
| 10.19 | 7564138 | SEAL, INTERCON TERMINATION | 26 |
| 10.20 | 7554589 | GIMBAL BOOT | 17 |
| 10.21 | MS28775/1-238 | PACKING PREFORMED | 16 |
| 10.22 | 7554770 | FILL PLUG | 28 |
| 10.23 | 7554595 | GIMBALLED HOUSING | 31 |
| 10.24 | 7554776 | INTCON CABLE BOOT | 35 |
| 10.25 | MS28775/1-238 | PACKING PREFORMED | 15 |
| 10.26 | BLANK | — | — |
| 10.27 | 7564124 | SPOOL, CABLE | 32 |
| 10.28 | M83248/1-205 | PACKING PREFORMED | 34 |
| 10.29 | M83248/1-205 | PACKING PREFORMED | 33 |
| 10.30 | 7554775 | SEAL CORE | 30 |
| 10.31 | 7556676 | CORE INTCON CABLE | 36 |
| 11.11 | 7564127 | TERMINAL INTCON CABLE | 37 |
| — | 7554780 | SEAL, CABLE CORE | 14 |
| — | 7555738 | SLEEVE TAPERED | 10 |
| | 7563620 | SEAL STRENGTH TERMINATOR | 20 |
| | 7564128 | NUT, TAPER | 27 |
| | 7564133 | PLATE, CONDUCTOR | 8 |
| | 7564144 | TERMINATOR, STRENGTH | 18 |
| | M83248/1-026 | PACKING PREFORMED | 29 |

# APPENDIX D

# PACIFIC MISSILE TEST CENTER

# TOLERANCE STUDY

# BSURE PLUG-IN TERMINATION

# PACIFIC MISSILE TEST CENTER
# TOLERANCE STUDY
# BSURE PLUG-IN TERMINATION

1.0 SUMMARY: No changes to detail components or sub-assemblies are recommanded. Any occurrence of assembly problems due to worst-case tolerance values may be easily correctad by selective component assembly.

2.0 BACKGROUND: At the request of the Naval Air Systems Command, Code AIR-630, and based upon questions raised in review of design documents by personnel from the Naval Facilities Engineering Command, a study was undertaken by Code 3144 of the Pacific Missile Test Center to determine whether any specified dimensions or their accumulated tolerance buildup might cause assembly difficulties for the propose design of the BSURE refurbishment, plug in, type SD cable termination, as represented in DL-00915 and associated shop drawings.

In arriving at final assembly results, absolute worst case tolerance accumulations were considered. Also investigated were assembly under nominal and low-end tolerance conditions and their effect on diametral clearances, part-to-part alignment, o-ring groove design, and Morrison seal design.

3.0 FINDINGS:

3.1 No evidence of diametral interference nor alignment problems could be found. All mating/interfacing components were investigated.

3.2 O-ring gland design on taper nut, part no. 7564128, was found to deviate slightly from manufacturer's (Parker-Hannifin Corp.) specifications. However, as it compresses the o-ring more, it will result in a better seal at low pressures while still functioning well at higher pressures, should a loss of cavity oil occur.

3.3 Morrison seal design and placement are acceptable at nominal dimensional values. This morrison seal (coreseal 7563636), under an unlikely accumulation of tolerance of six individual parts, is still acceptable for high pressure service, and will perform very well under the current, pressure-balanced design.

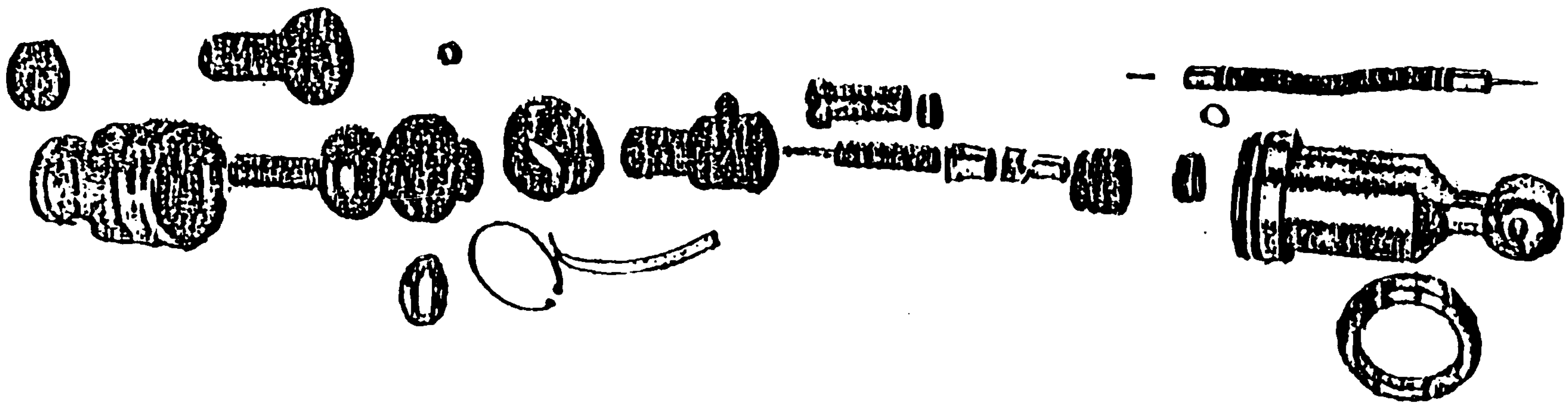
3.4 The load bearing plate (p/n 7564131), the male ground contact (7564120), the leveled snap ring (7564546) and its groove exhibit no assembly problems at nominal dimension values. However, under worst-case tolerance accumulation, only .010" of the snap ring would seat in its groove. This is easily recognizable during assembly and can be corrected at that time by choosing other parts or by remachining the male ground contact to nominal or low-end dimensions.

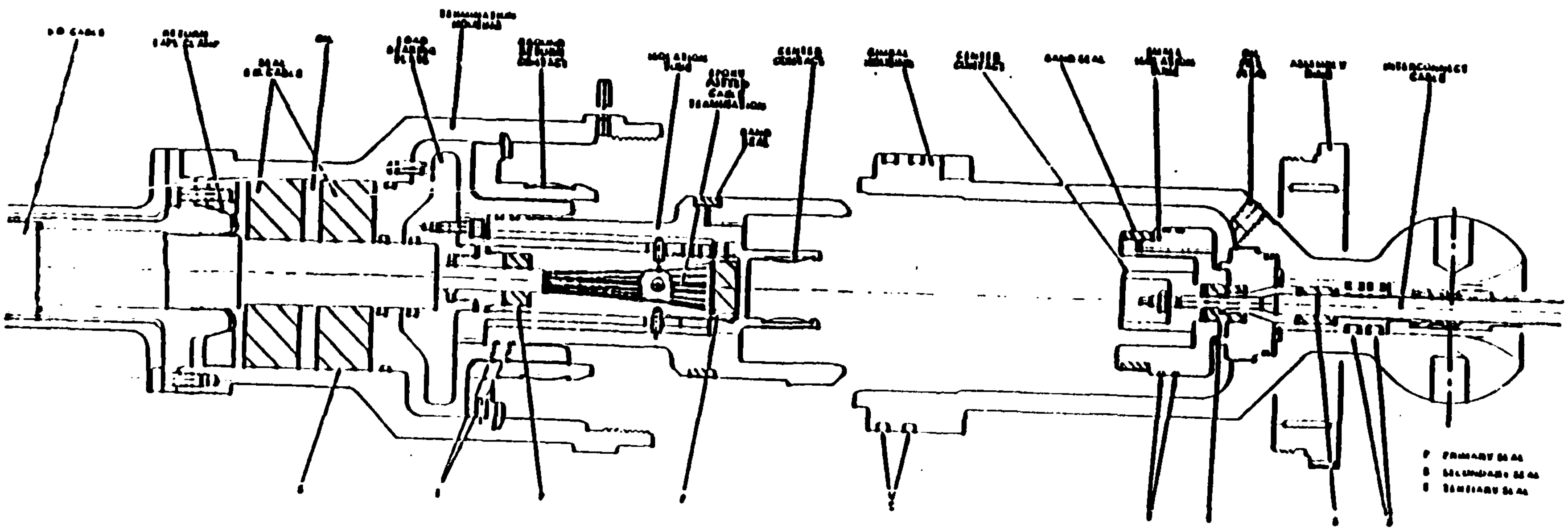
## 4.0 RECOMMENDATIONS:

4.1 No dimensional, tolerance, or part changes are recommended.

4.2 Assembly drawings should be accompanied by contractor manufacturing routings which will alert shop assemblers to check and, if necessary, correct areas discussed in paragraph 3.0. Corrective action may be effected through selected component assembly or remachining of certain components.

# SD CABLE TERMINATION





# APPENDIX E

## BSURE SD TERMINATION SEAL TOLERANCE STUDY

## TOLERANCE ANALYSIS CONDUCTED AT DELCO ELECTRONICS, FEBRUARY 1982

## Reliability Analysis of BSURE In-Water Electronics

NOTE: This analysis was performed on an early design of the electronics system which differed slightly from the design actually used. The design analyzed included some parts that were not included in the final design, giving reliability results that were slightly lower than those computed by the manufacturer of the system. This analysis is included in the interest of completeness in reporting the analyses performed by the Design Review Team and because the results are considered somewhat indicative of the reliability of the system.

3 FEB 82

# BSURE SD TERMINATION

# SEAL TOLERANCE STUDY

TOLERANCE ANALYSIS CONDUCTED AT

DELCO ELECTRONICS

FEBRUARY 1982

Encl (Q) to PACMISTESTCEN Ltr 3143 4 MAR 198
SSIC 3912 Ser L475 of

MORRISON SEAL 14 & 20

(LOCATED INSIDE STRENGTH TERMINATOR 7564144)

o ANALYSIS RESULTS

UNDER WORST CASE TOLERANCE CONDITIONS SEALS COULD OVERLAP INTO TAPERED AREA BY .044 14 AND .042 20

o RECOMMENDATION

1. CHANGE TERMINATOR, DELCO DWG 7564144, AS FOLLOWS TO PROVIDE MORE SPACE FOR SEAL 20

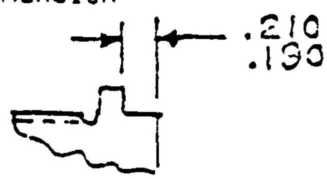
| | | | |
|---|---|---|---|
| FROM: | 3.480 | TO: | 3.520 |
| FROM: | 1.000 | TO: | 1.040 |
| FROM: | .390 | TO: | .430 |
| FROM: | .780 | TO: | .820 |

2. CHANGE NUT, DELCO DWG 7563617, TO AS FOLLOWS TO PROVIDE MORE SPACE FOR SEAL 14

FROM: .670/.660 TO: .630/.620

DELETE .130/.120 DIMENSION

ADD .210/.190 DIM



MORRISON SEAL 26 7564138

- **ANALYSIS RESULTS**

  UNDER WORST CASE TOLERANCE CONDITIONS, AN ADEQUATE GLAND VOLUME IS AVAILABLE FOR THE SEAL.

- **RECOMMENDATION**

  USE EXISTING DESIGN

O-RING SEAL (29)

(LOCATED ON TAPER NUT 7564128

- ANALYSIS RESULTS

  UNDER WORST CASE TOLERANCE CONDITIONS O-RING COULD BE OVERLAPPING TAPERED SURFACE OF GIMBAL HOUSING 7564123 BY .001.

- RECOMMENDATION

  INCREASE LENGTH OF SEALING SURFACE ON GIMBAL FROM .350 TO .360.

REF DELCO DWG 7564123

MORRISON SEAL 7563636
(LOCATED IN SPOOL 7564124 (30)

- ANALYSIS RESULTS

  UNDER WORST CASE TOLERANCE BUILDUP, THE "SEAL" VOLUME WILL EXCEED THE AVAILABLE VOLUME BY .008 $IN^3$.

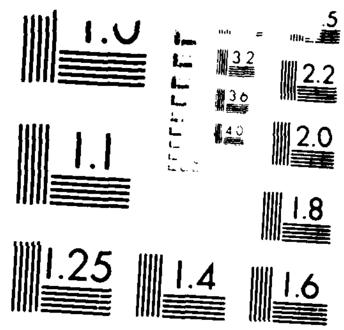
- RECOMMENDATION

  1. INCREASE SPOOL CAVITY LENGTH FROM .88 TO .90, REF DELCO DWG 7564124.

  2. DECREASE SEAL LENGTH FROM .37 $\pm$.02 TO .37/.35 AND SPECIFY .37/.35 BE MET WHEN ON THE .275 - .276 MANDRELL. REF. DELCO DWG 7563636

AD-A168 658 CABLE TERMINATIONS FOR THE BSURE (BARKING SANDS UNDERWATER RANGE EXPANSIO..(U) NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON DC CHESAPEAKE.. 1985 2/3

UNCLASSIFIED CHES/NAVFAC-FPO-1-85(12) F/G 13/10.1 NL


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
3.2
3.6
4.0

## O-RING GLAND DESIGN

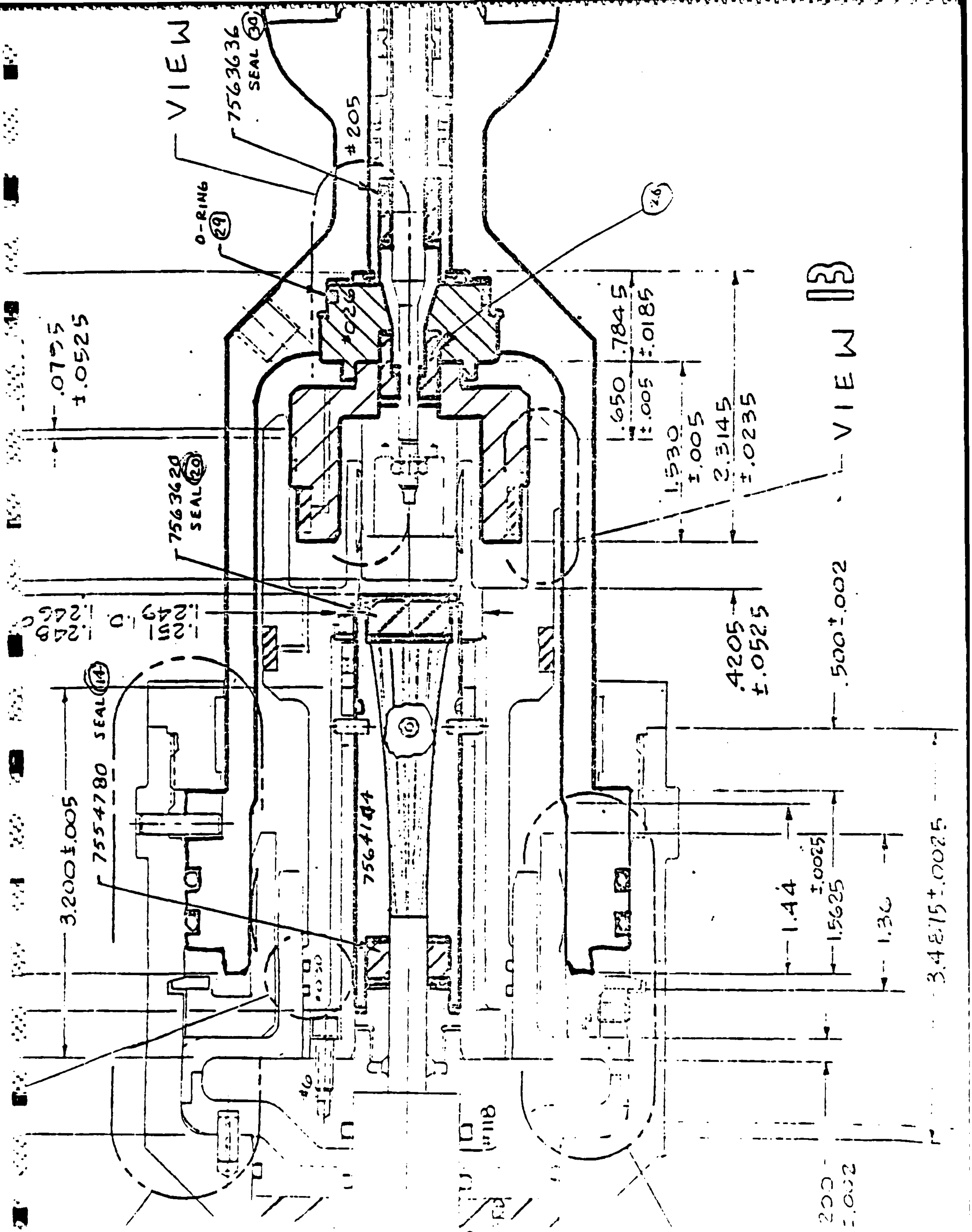
### ANALYSIS RESULTS

industrial static seals

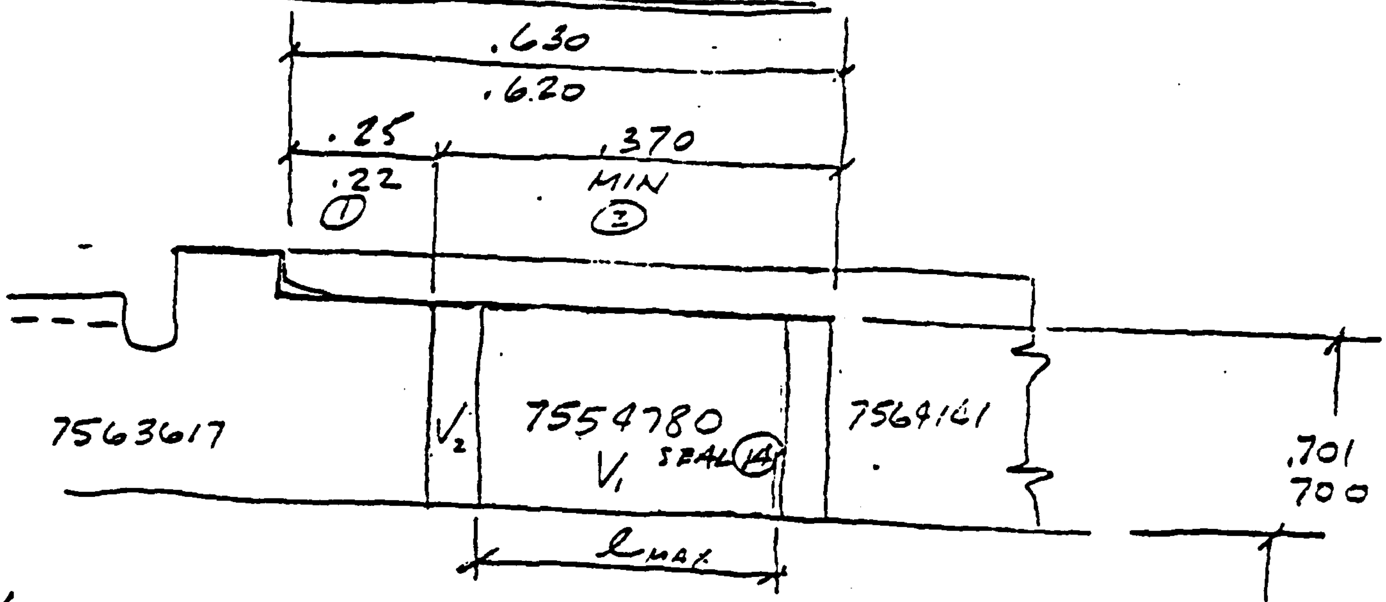
O-RING GLAND DESIGN IS PER PARKER DESIGN HANDBOOK OR 5700 FOR STATIC INDUSTRIAL TYPE O-RING SEALS.

### RECOMMENDATIONS

RETAIN PRESENT DESIGN


VIEW
7563636 SEAL 30
#205
O-RING 29
26
.0775 ±.0525
.7845 ±.0185
.650 ±.005
1.530 ±.005
2.3145 ±.0235
VIEW B
7563620 SEAL 20
.4205 ±.0525
.500±.002
3.200±.005
7554780 SEAL 14
1.44
1.5625 ±.0025
1.30
#118

SEAL (14) 7554780




$V_1 MAX$ 7554780 $= .7854(.7455^2 - .3255^2) \times .35$

$V_1 MAX = .12365 \text{ in}^3$

$V_2 MIN$ 7564141 $= .7854(.700^2 - .331^2) \times .37$

$V_2 MIN = .11055 \text{ in}^3$

$$l_{MAX} \text{ INSTALLED} = \frac{.12365}{.7854(.700^2 - .331^2)} = .4138 \text{ in seal}$$

$- .3700$ in gland

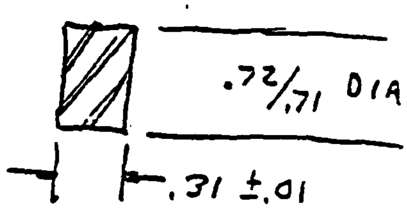
⟨.0438⟩

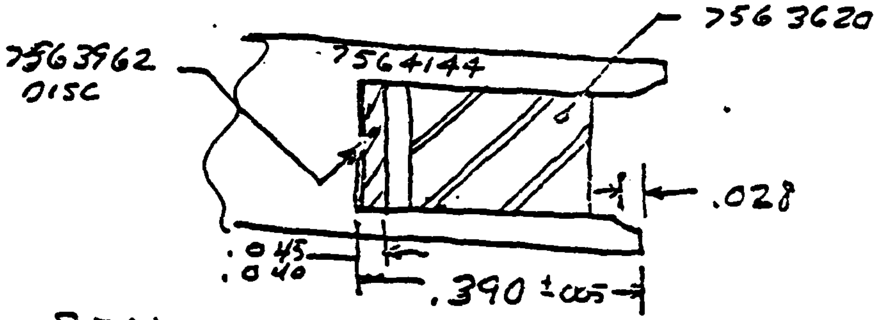
interference

| | |
|---|---|
| .665 | ±.005 |
| − .305 | ±.005 |
| .360 | ±.010 |
| − .25 | ±.005 |
| .35 | ±.015 |

.620
− .250
② .37 MIN

SEAL (20) 7563620




SEAL VOLUME MAX

$V_s = \frac{\pi}{4} D^2 H = \pi \times (.72)^2 .32$

$V_s = .13028$

CAVITY VOL. MAX

$V_c = \frac{\pi}{4} D^2 H = \frac{\pi}{4} \times (.685)^2 \times .3115^*$

$V_c = .1147 \text{ in}^3$

$V_s - V_c = .01558 \text{ in}^3$

INTERFERENCE CONDITION

$$\begin{array}{r} ^*\ .385 \\ -\ .045 \\ \hline .340 \\ -\ .028 \\ \hline .312 \end{array}$$

LGTH MAX INSTALLED

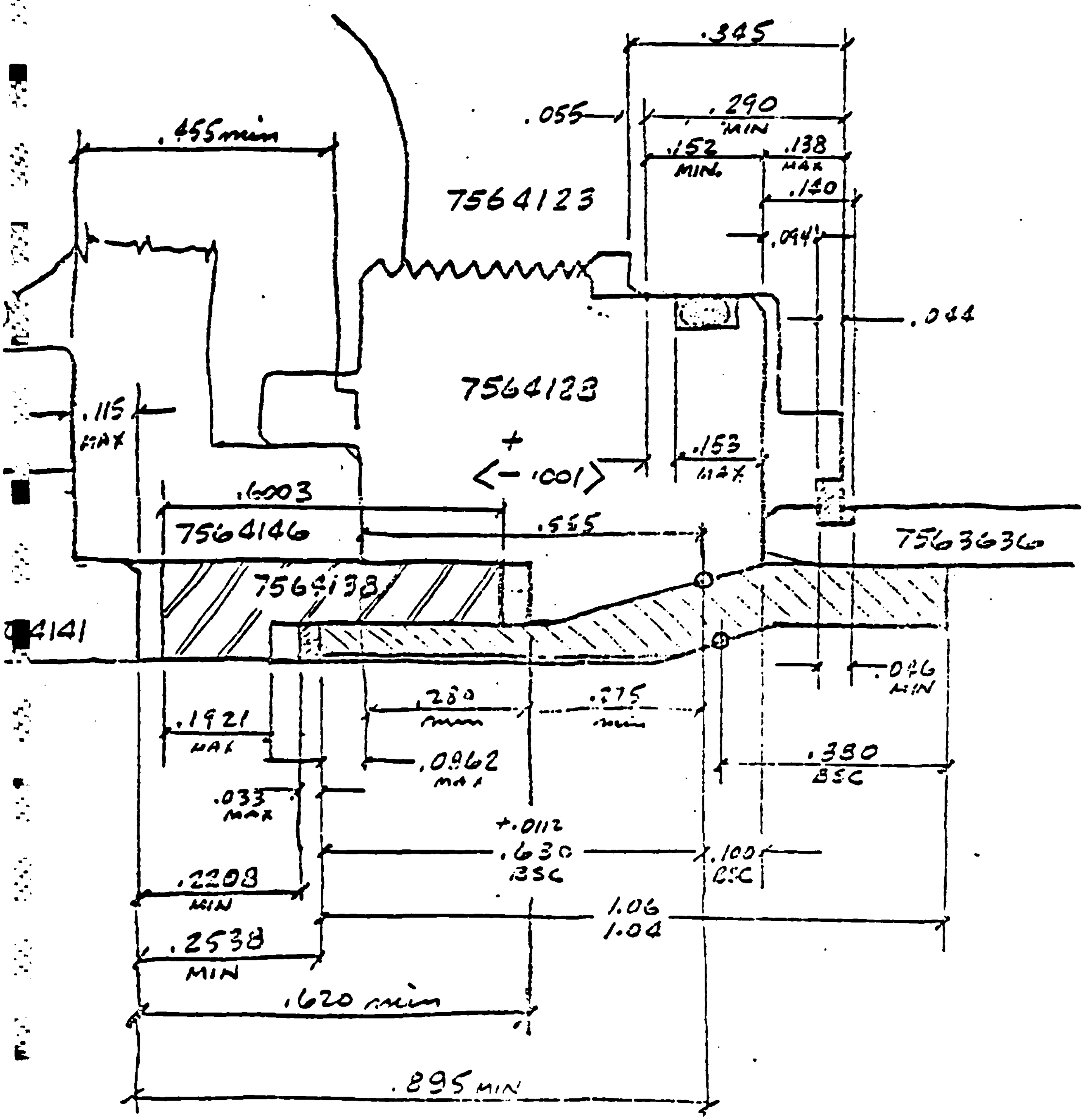
$\frac{.13028}{.7854 \times (.685)^2} = \frac{.13028}{.3685} = .3535$

CAVITY LENGTH MIN

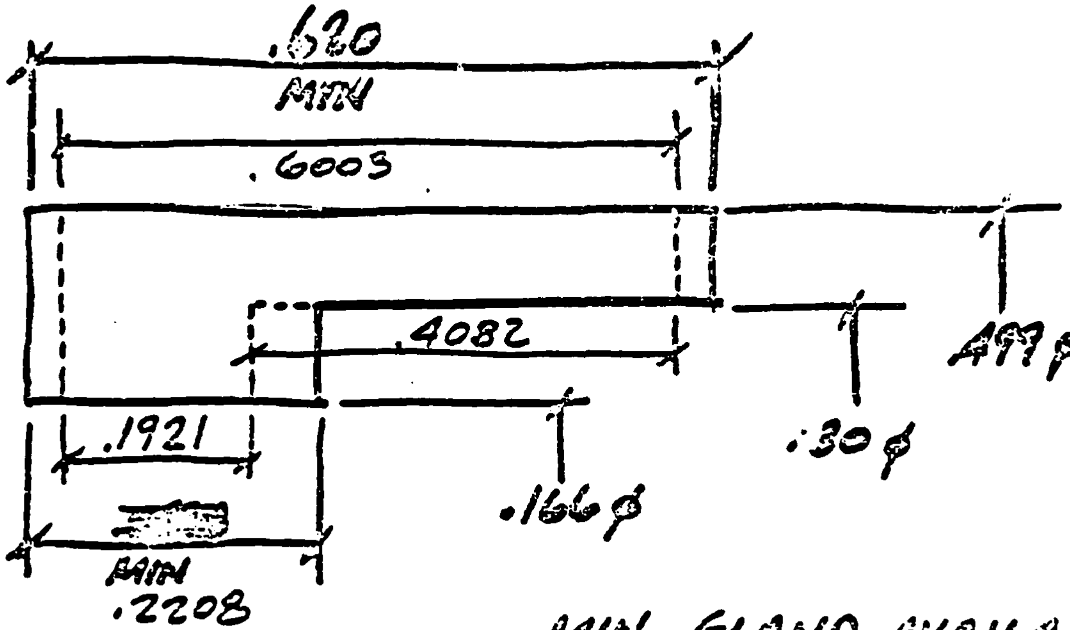
$.385 - .045 - .028 = .312$

$$\begin{array}{r} .3535 \\ .312 \\ \hline \boxed{.0415} \end{array}$$ INTERFERENCE

SEAL (26) 7561438



SEAL 26 CONT'D




MIN. GLAND AVAILABLE

## MAX VOLUME SEAL 7564138

$$V_1 = .7854\left(.52^2 - .142^2\right) \times .17 = .03341 \text{ in}^3$$

$$V_2 = .7854\left(.52^2 - .26^2\right) \times .32 = .05097 \text{ in}^3$$

## MAX INSTALLED LENGTH

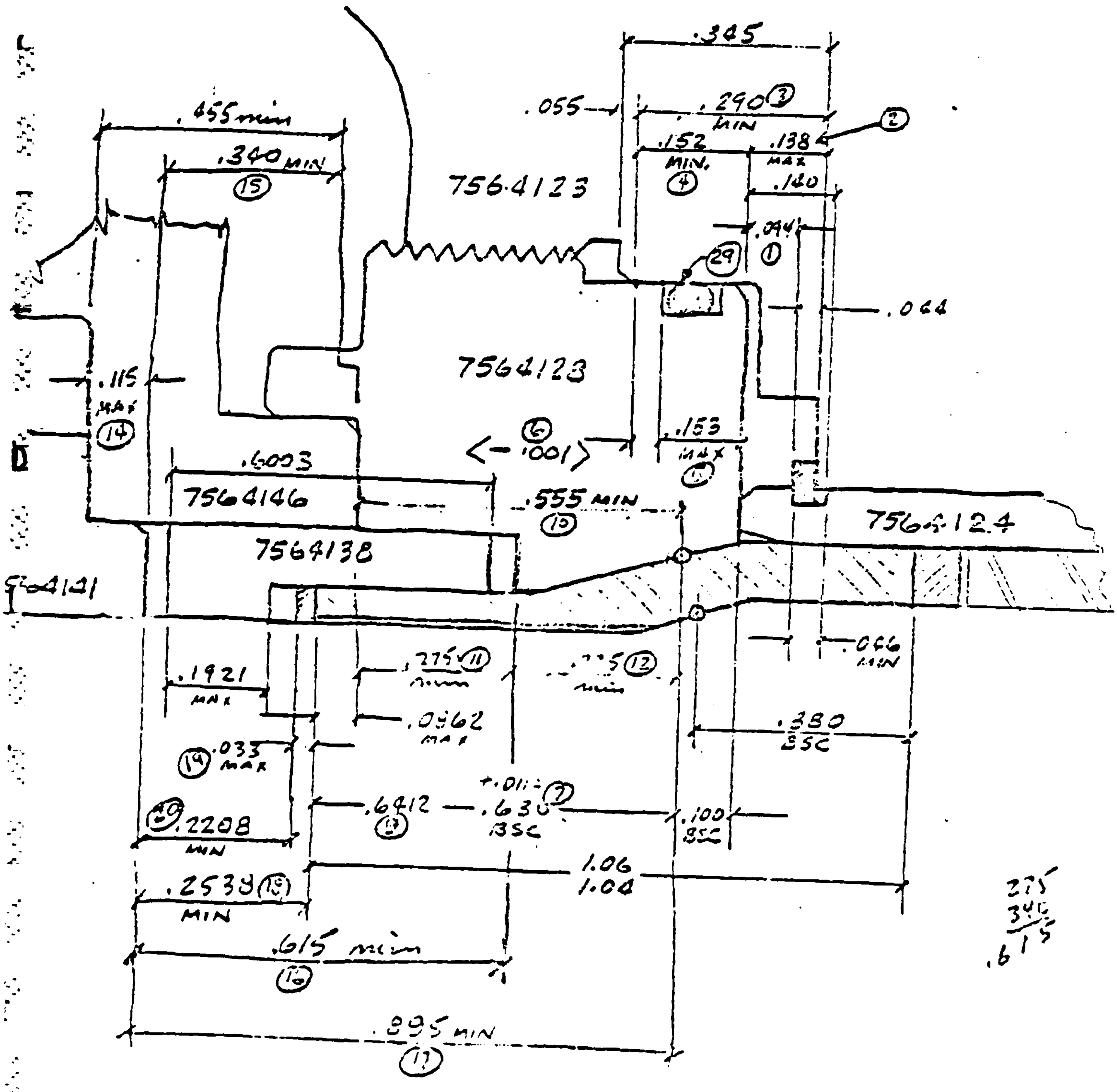
$$l_1 = \frac{.03341}{.7854\left(.499^2 - .166^2\right)} = .1921$$

$$l_2 = \frac{.05097 \text{ in}^3}{.7854\left(.499^2 - .30^2\right)} = .4082$$

.6003

installed length req'd

ORING SEAL 29



.13 ±.01
- .0475 ±.0015 } 7564124

(1) .0825 ±.0115
+ .042 ±.002 RETAINER RING

(2) .1245 ±.0135

.350 ±.005
-.04 ±.015 } 7564123

(3) .310 ±.020
(2) -.1245 ±.0135

(4) .1855 ±.0335

.1855
-.0335
.1520 MIN

(5) .148 ±.005 7564128

.148
+.005
.153 MAX

(6) <-.001>

(7) .630 BASIC
(8) +.0112
(9) .6412 MAX

.660 ±.005
- .100 BASIC

(10) .560 ±.005

.230 ±.005

(12) .280 ±.010

7564128

(13) .460 ±.005 7564146
(14) -.110 ±.005 7564141

(15) .350 ±.010
(11) +.280 ±.005

(16) .630 ±.015

| | | |
|---|---|---|
| (13) | .350 | ±.010 |
| (10) | + .560 | ±.005 |
| (17) | .910 | ±.015 |
| (9) | − .6412 | MAX |
| (18) | .2688 | ±.015 |
| (19) | − .030 | ±.003 |
| (20) | .2388 | ±.018 |
| | − .1921 | MAX SEAL LENGTH INSTALLED |
| | .0467 | ±.018 |

−.018 = .0287 MIN CLEARANCE

## MAX VOLUME CALCULATION:

$V = \frac{1}{4}\pi\left[(d_1^2) - (d_2^2)\right] \times l$

$V = .7854\left[(.546)^2 - (.276)^2\right] \times .39$

$V = \underline{.06798}\ in^3$ max

$d_1 = .276 + (2 \times .135)$

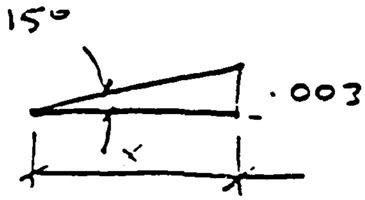
$d_1 = .546\ \phi$

$d_2 = .276\ \phi$

$l = .39$

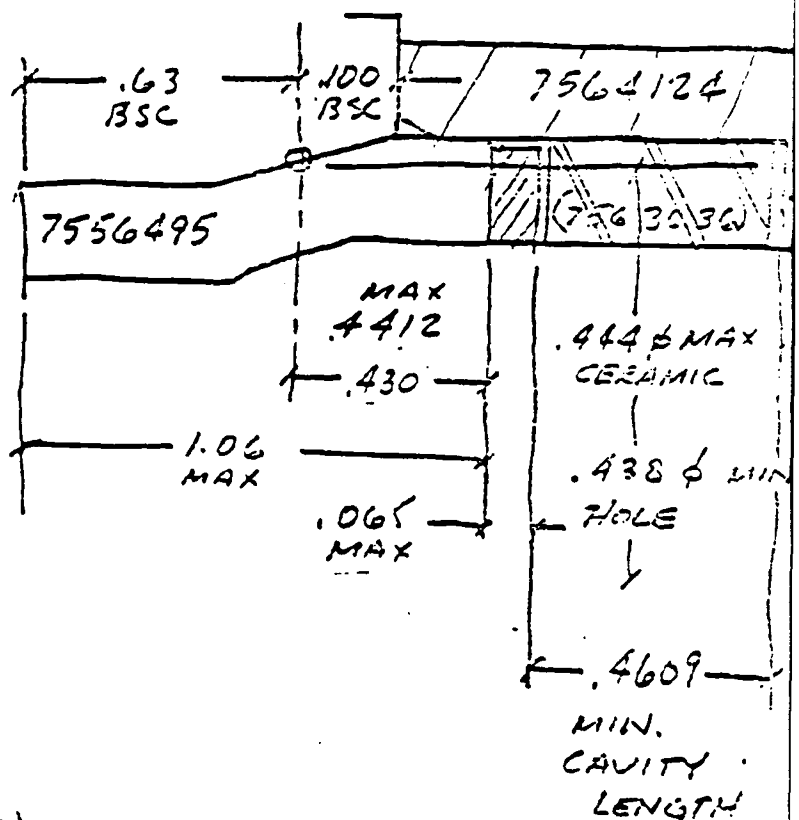
---

## MIN VOLUME CAVITY:




$.444\ \phi$
$.438\ \phi$
$\frac{.006}{2} = .003$

$.003 \times \cot 15° = .0112$
$+ .4300$
$.4412$




.87 MIN DEPTH (7564124)
$-$ .100 BSC
$.970 - (.4412 + .065) = .4609$

$V = .7854\left[(.498)^2 - (.288)^2\right] \times .4609 = \underline{.0598\ in^3}$

SEAL (756363C)

MAX length when installed in min $\phi$ gland.

$V_1 = .06798 \text{ in}^3 \qquad V_1 = V_2$

$V_2 = .06798 \text{ in}^3 = .7854\left[\underbrace{(.498)^2-(.288)^2}_{.16506}\right] \times \ell$

$$\ell = \frac{.06798}{\underbrace{[.498^2 - .288^2]\,.7854}_{.12764}}$$

$\ell = .\cancel{4485}$

$\ell_1 = .52438 \text{ in}$

$-\ell_2 \quad .4609$

$\langle .06348 \rangle$ interference at worst case.

---

| AVAIL. VOLUME GLAND | MAX VOLUME SEAL | $\Delta V$ |
|---|---|---|
| $.0598 \text{ in}^3$ | $.06798 \text{ in}^3$ | $\langle -.00818 \text{ in} \rangle$ |

| AVAIL LENGTH GLAND | MAX LENGTH SEAL | $\Delta L$ |
|---|---|---|
| 4609 in | .5244 in (.39 MAX INITIAL DIM) | $\langle -.0635 \rangle$ |
| | .4975 (.37 MAX INITIAL DIM) | $\langle -.0355 \rangle$ |

3143
23 February 1982

## COMMENTS ON CHESAPEAKE DIVISION TOLERANCE ANALYSIS OF BSURE CABLE TERMINATION SEALS

1. Possibly due to a lack of familiarity with the BSURE connector, several errors were made by CHESDIV in their analysis of the BSURE Cable Termination Seals.

1.1 MORRISON SEAL NO. 30

1.1.1 CHESDIV page 1 of 29: Seal No. 30 is 0.37 inches long not 0.36.

1.1.2 CHESDIV page 3 of 29: Two dimensions were called out on the drawings as basic and are not subject to tolerances as shown here.

1.1.3 CHESDIV page 3 of 29: In computing the minimum cavity length 0.10 inch was not added into the computation.

1.1.4 Delco page 4 shows a final possible interference of 0.008 $in^3$. This is from a tolerance build up on six dimensions. A condition that would be present 0.0002% of the time. The Delco analysis shows the corrective steps that will be taken to eliminate even that remote possibility.

1.2 O-RING SEAL NO. 29

1.2.1 a. CHESDIV page 5 of 29: Dimension 0.045 should be 0.055, dimension 0.143 should be 0.153 for max condition, and dimension 0.14 should be 0.138 for maximum condition.

1.2.2 Delco page 3 shows a 0.001 inch exposure of the O-ring groove beyond the level under worst tolerance case. They will increase the sealing surface on the gimbal by .01 inch to preclude this problem.

1.3 MORRISON SEAL NO. 26

1.3.1 CHESDIV page 9: The wrong backup seal ring was used in this analysis.

1.3.2 Delco page 2: Shows adequate gland volume for the seal. No change to be made.

1.4 MORRISON SEALS NO. 14 AND 20

1.4.1 CHESDIV page 14: The 7563620-002 seal is not used in this assembly

1.4.2 Delco page 1: The seals could overlap into their tapered areas. The terminator end has been lengthened and the 7563617 nut is shortened to eliminate these problems under worst case tolerance conditions.

# APPENDIX F

# FAILURE MODES AND EFFECTS ANALYSIS

# OF

# BSURE CONNECTOR SEALING SYSTEM

# BY

# PACIFIC MISSILE TEST CENTER

Prepared by:

Robert Polley, Code 3143

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## FOREWORD

This document was prepared to provide information on the failure modes of the BSURE plug in cable connector sealing system and the effects of those failures on the BSURE system.

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Systems Division

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W. R. Hattabaugh
Head, Range
Development Department

1. Introduction. This report presents the Failure Modes and Effects Analysis (FMEA) performed on the seals of the in-water equipment of the Barking Sands Underwater Range Expansion (BSURE) System. The FMEA is done in accordance with Task 101 of MIL-STD-1629A with the following exceptions: The FMEA is done only for the seals of the cable connector, Terminal and Transmission Unit (TATU), hydrophone, and tether cable. The identification numbers do not follow MIL-STD-780E but follow the 1970 version of MIL-STD-1629 and the FMEA worksheet format is simplified.

2. Summary. Appendix A presents sketches of the sealing system based on the BSURE as-built drawings of 1976 and the cable connector drawings of 1981. Appendix B presents the FMEA based on the sketches of Appendix A. Appendix C is a cross index of identification numbers to Delco drawing numbers. Appendix D presents schematics of the sealing systems with the seals shown as a series of barriers.

3. Discussion.

3.1 Environment. The in-water units operate in sea water at a depth of 15,000 feet. They lie on the bottom in basalt rock and a thin layer of sandy mud. The temperature at that depth is 3°C. The units are installed from a cable ship. The maximum expected tensile loads during deployment are from 5,000 to 8,000 pounds at the surface, gradually decreasing to zero at the bottom (the cable is layed with 4% slack.) The maximum torsional load expected is 2 to 5 foot-pounds. The TATU will experience a minimum of 180° rotation depending on the swing of the cocoon and the waves. The maximum temperature of the surface is 32°C. However, the TATUs are stored below deck in air-conditioned spaces and are only in the sun a short time.

3.2 Parts Quality. All parts are 100% inspected for defects and deviations.

3.3 Testing.

3.3.1 Metals. All metal housings are helium leak tested.

3.3.2 Seals. All assembled seals are helium leak tested except those in the cable connector. Those are tested by vacuum.

3.3.3 Assemblies. All assemblies are pressure tested at 3°C and 7,500 psi for two hours with the exception of the cable connector.

4. Failure Definition.

4.1 Failure can occur such that the individual TATU no longer works (e.g., the hydrophone tether cable parting) but the rest of the string that it is in still works. This failure is non-catastrophic and the system will still function but in a slightly degraded mode around that TATU position.

4.2 Failure can occur such that the individual TATU no longer works (e.g., a short in the cable connector) and the string seaward of its position no longer works. This failure is catastrophic as the entire string will eventually be shut off.

4.3 Failures other than the TATU seals are not addressed in this FMEA. The mechanical hardware has been proof-tested (i.e., installed) at 15,000 feet for five years. There have been no problems with any of the electronics in the TATU or the shore system. There have been no problems with deployment of the TATUs, the hydrophones, or their tether cables.

5. Failure Modes

5.1 The Primary Seals of the BSURE TATU connector are the two seals at either end of the strength terminator. As primary seals, they are the only seals that are operating under the full ambient load for the life of the connector. The primary seals are the only seals in the connector that operate under full load (7500 psi) for 20 years, the rest of the seals in this connector are pressure balanced, that is the pressure is the same on both sides of the seal.

5.2 The intrusion of sea water into the connector is only possible if one of the primary seals should fail or if there is some porosity in the strength terminator or inner copper jacket outside of the primary seal. If either of the primary seals should fail then the gimbal housing would be forced down by the outside sea pressure and oil would be pushed into the voids in the strength member of the SD cable. The amount of oil that could be pushed out would be small, on the order of 40 - 50 cc's. The connector however would still be oil filled and no sea water could enter the cable at this time. However, the load is now taken by the secondary seals, the o-rings (10.21) and the fill plug (10.22). Although the connector is now considered to be operating at a degraded mode in that it is not operating at its full design capability it is working as the old BSURE Terminator was designed to work. The secondary seals of the new connector are the same seals that were operating as the primary seals in the old connector design. As that design was made with a 20 year life this implies that the secondary seals of the new connector should have a 20 year life if they are ever called upon in the event of a primary seal failure. In this condition (primary seal failure) the connector is still filled with oil, there has been no sea water intrusion and the connector will still function as intended. In the event that the secondary sealing system failed sea water would not be present in the connector. The tertiary seal would take the full load and likewise be good for 20 years.

5.3 In the event of outer cable jacket failure there is no degradation of the connector. If during recovery the cable is cut down into the center conductor the center conductor will be flooded; however, this cable can be used for re-installation because the present system is capped at the strength terminator and pressure balanced so that water can't be forced up the cable into the connector. It is interesting to note that once the cable is flooded the connector is now truely pressure balanced. That is, the primary seals are no longer loaded. Thus, no driving force can be developed to allow the intrusion of sea water into the connector.

6. Reliability Block Diagram Explanation

6.1 Some explanation is required to view the reliability block diagrams (Appendix B) in the proper light. Each of the blocks represent a particular physical part in the seal system through or around which a leakage could take place. The reliability block diagram has to be reviewed with the sketch of the particular seal system to sea where the leak paths could lie. It must be remembered that the leak paths are not only between the interfaces of the parts but could also be through the parts themselves due to porosity or pinholes. For example, at the interface of the first seal of the connector (10.02), with the housing (10.01) and the cable (10.03), the leakage could not only be at the interfaces but through the parts themselves. This can be more clearly seen in the schematic diagram in Appendix D.

In order to develop the reliability equation careful accounting must be taken by view the sketch of the area of concern as well as the reliability block diagram. A carefu design analysis must not only pay attention to the piece parts but also to the suppli the system quality control, quality control of piece parts and the assembly of those parts.

## 7. Design History

7.1 The original BSURE cable termination was designed to be a non pressure balanced connector, that is the oil on the inside would not be at the same pressure as the sea water on the outside. All the pressure would be held by the CuNi outer shell and the seals. The original BSURE termination was extensively tested in the laboratory under pressure and under tension, even going so far as to install two TATUs and one repeate in the ocean near Point Mugu. When the TATUs were installed at Barking Sands, however, several problems were encountered causing the loss of several hydrophones.

Upon examination of recovered BSURE hardware, these problems were classed into two categories; One, a cable termination pull out and two, leakage. It is felt that both of these problems have been solved.[1] The cable termination pullout problem has been solved through extensive testing in the Materials Laboratory at Point Mugu, bringing about the development of a new epoxy-mica mixture and a redesigned strength termination tube. The leakage problem has been solved by the redesign and testing of the sealing system for the SD cable. None of the other seals in the BSURE connecto system have shown any indication of failure in any of the recovered hardware to this date.

7.2 A second termination design was used to terminate the anode to the SD cable for the repair of A and B string. The major changes were that the cable connector was allowed to float, so that its interior cavity would be pressurized, also the ground pin and high voltage pins were coated with RTV silicone rubber to isolate them in the unlikely event of salt water intrusion.

7.3 When the Underwater Communication System Termination was designed this idea was carried further. The sealing system for the SDcable was redesigned along the lines that had been proven in seal testing at Delco, the new strength terminator was used along with the mica mixture. The coil cable assembly was still retained but oil filled silicon rubber boots were placed over the ground and high voltage pins rather than trying to coat RTV silicon rubber over them. This design also used the floating piston effect to pressurize the internal cavity of the connector.

7.4 The present BSURE termination design builds on all these ideas proven in actual installations and extensive laboratory tests. It is a pressure balanced design. However, instead of using the coiled cable assembly it uses the housing itself to carry the electrical ground and a redesigned center contact to carry the high voltage, relying on Multi-Lam contacts to provide a reliable contact thru the sliding connection. The same design concept used in UCS and proven in the laboratory test fixture is used to seal the SD cable entry into the connector and the concept of isolating the high voltage from the ground, is used. Thus, it can be seen that the present BSURE cable connector design is not a new group of untried components but is the result of a gradual evolution from one design that nearly worked, to a design that has been well proven both in a laboratory ocean simulator test chamber and by installation in the ocean at Barking Sands.

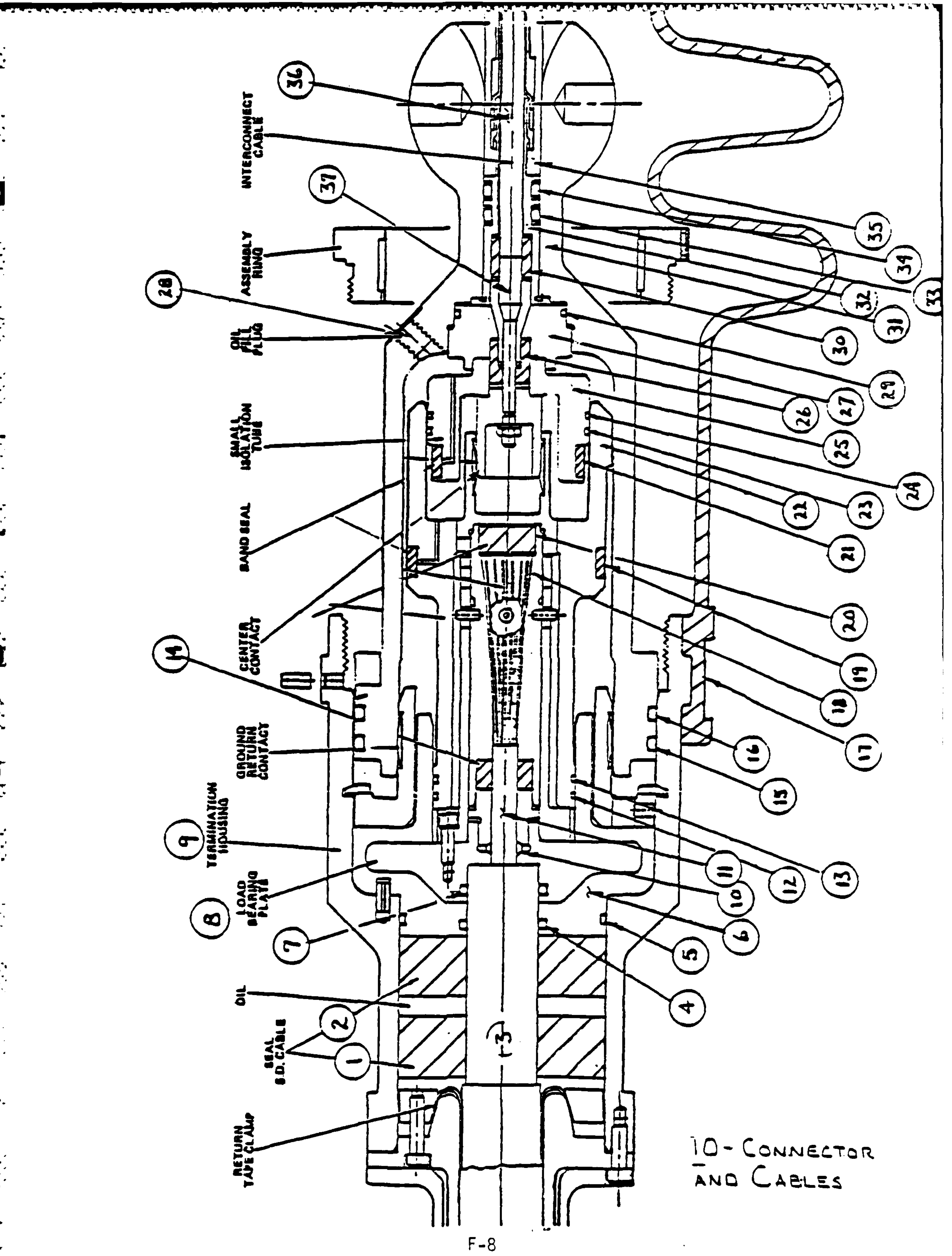
---

[1] Robert Polley, "SD Underwater Cable Strength Termination Design and Testing," No 3100-1-81 Capabilities Development Department, Code 3143, Pacific Missile Test Center, Point Mugu, CA.

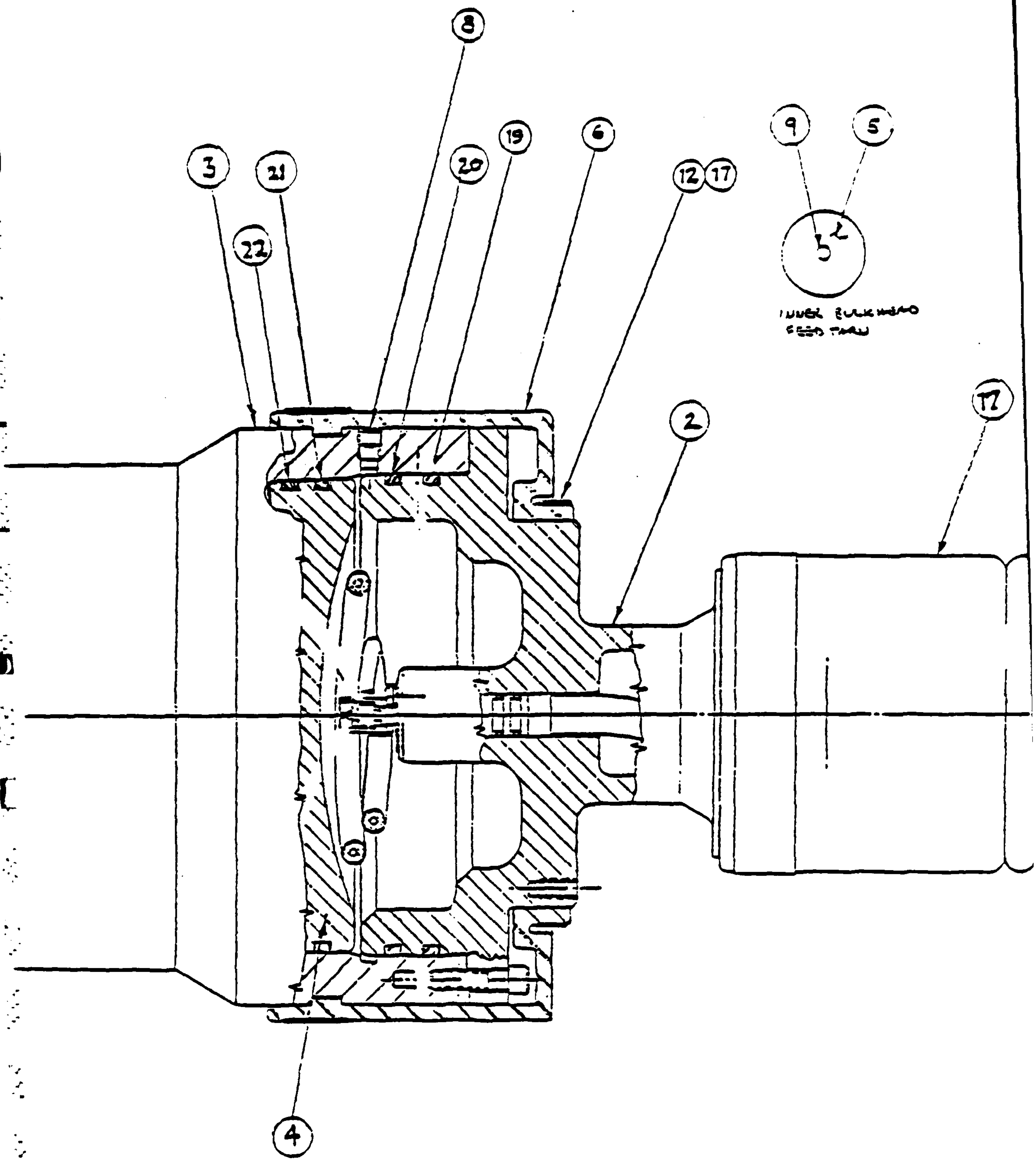
APPENDIX

A

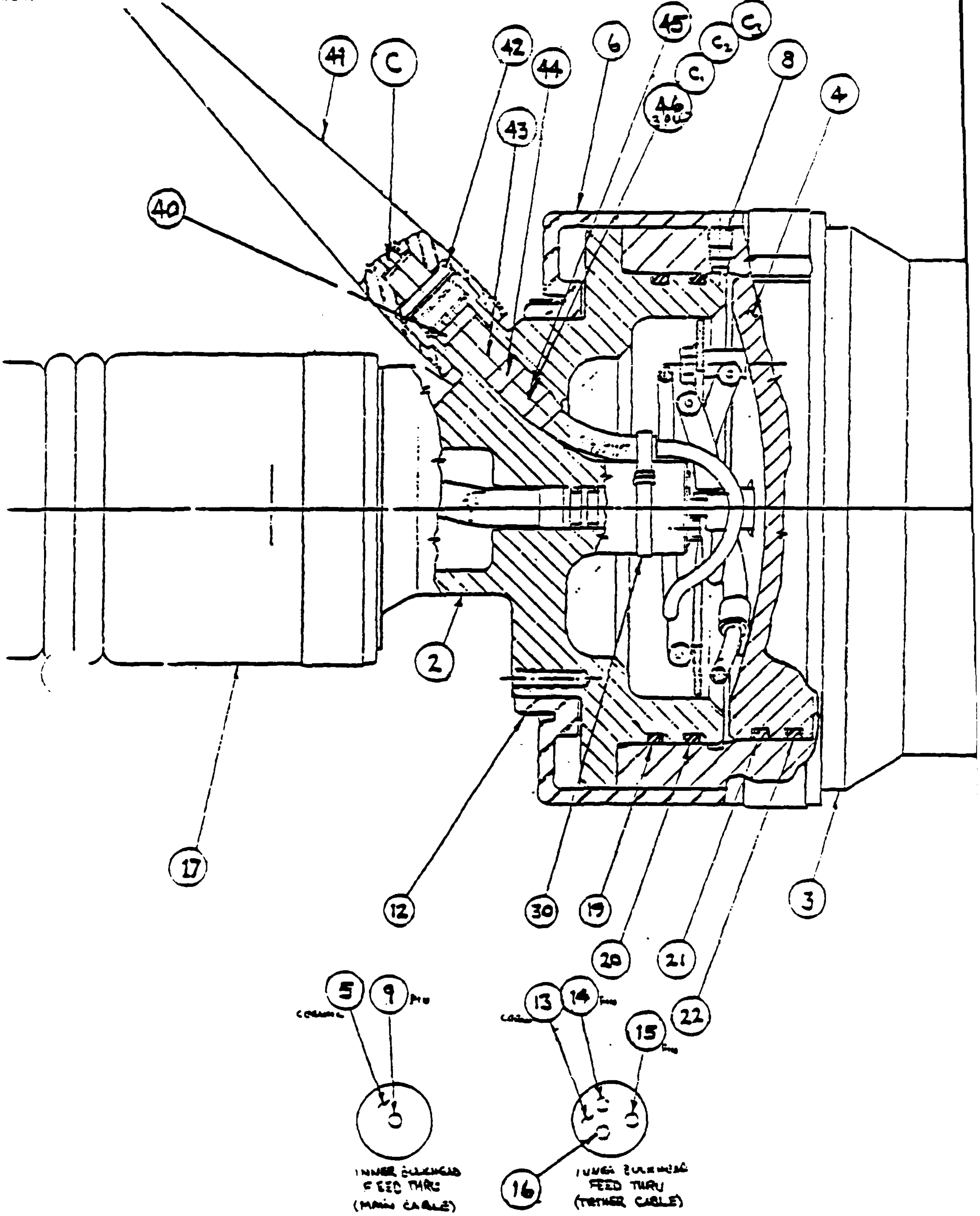
SKETCHES OF SEALING SYSTEM




10 - CONNECTOR AND CABLES

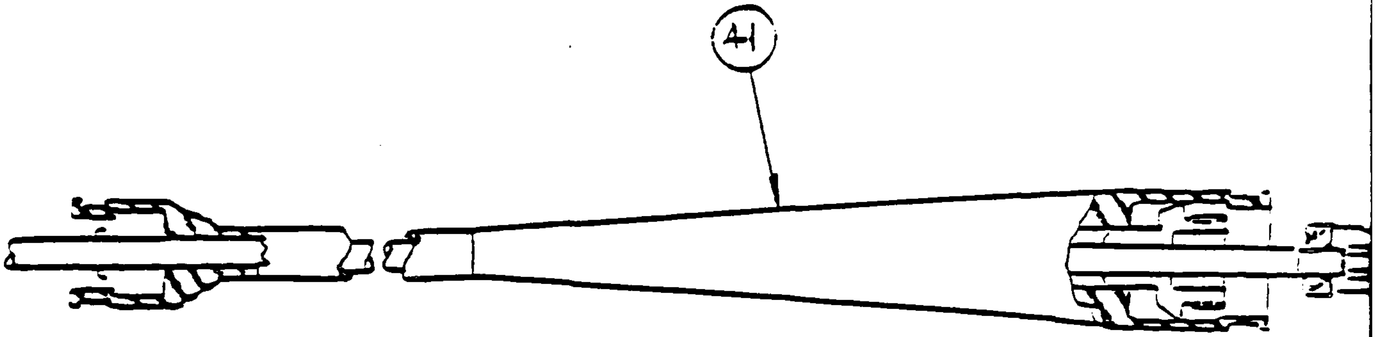


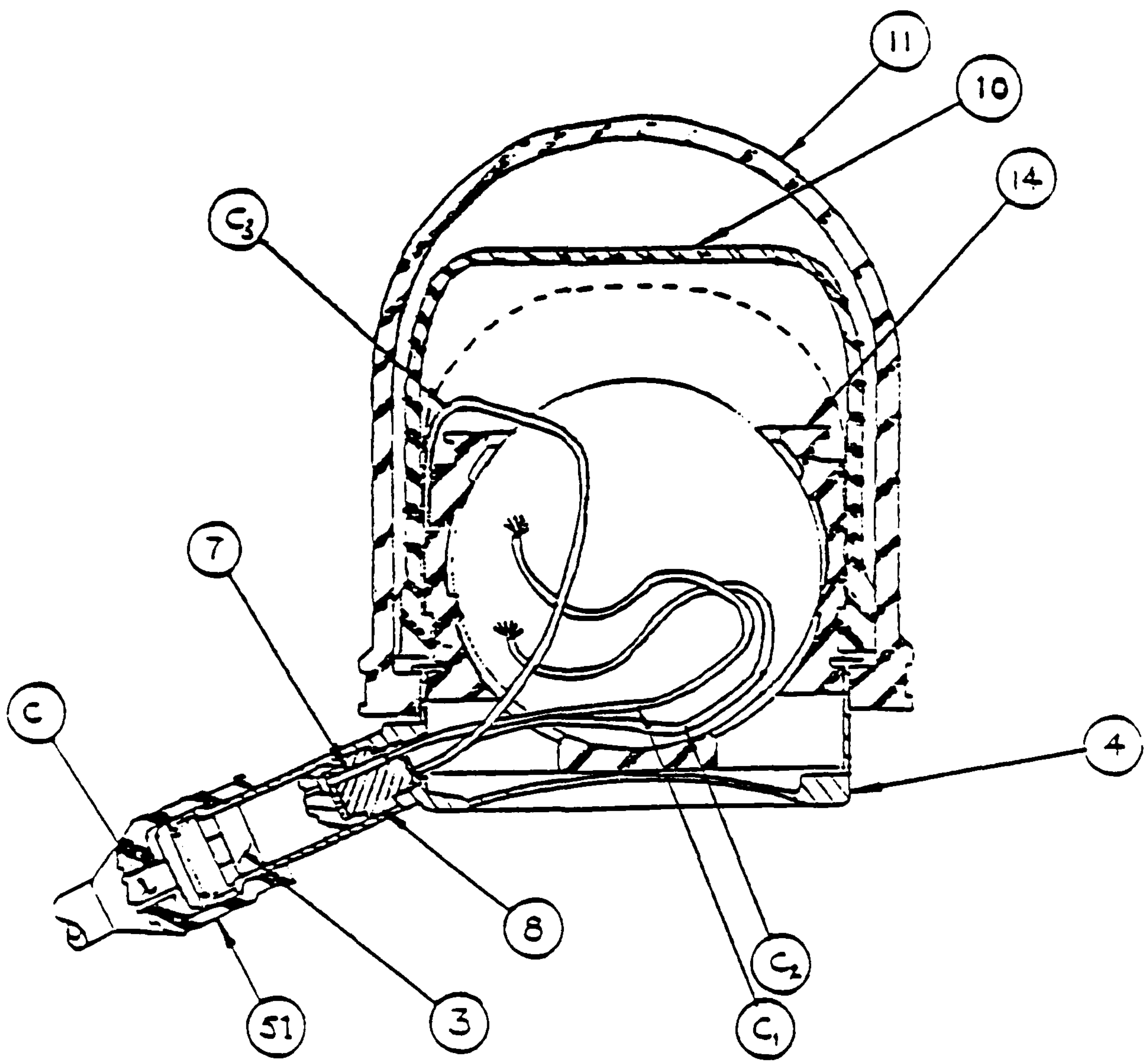

20-TATU END CAP




30-TATU ENDCAP, TETHER END

40-HYDROPHONE AND TETHER CABLE



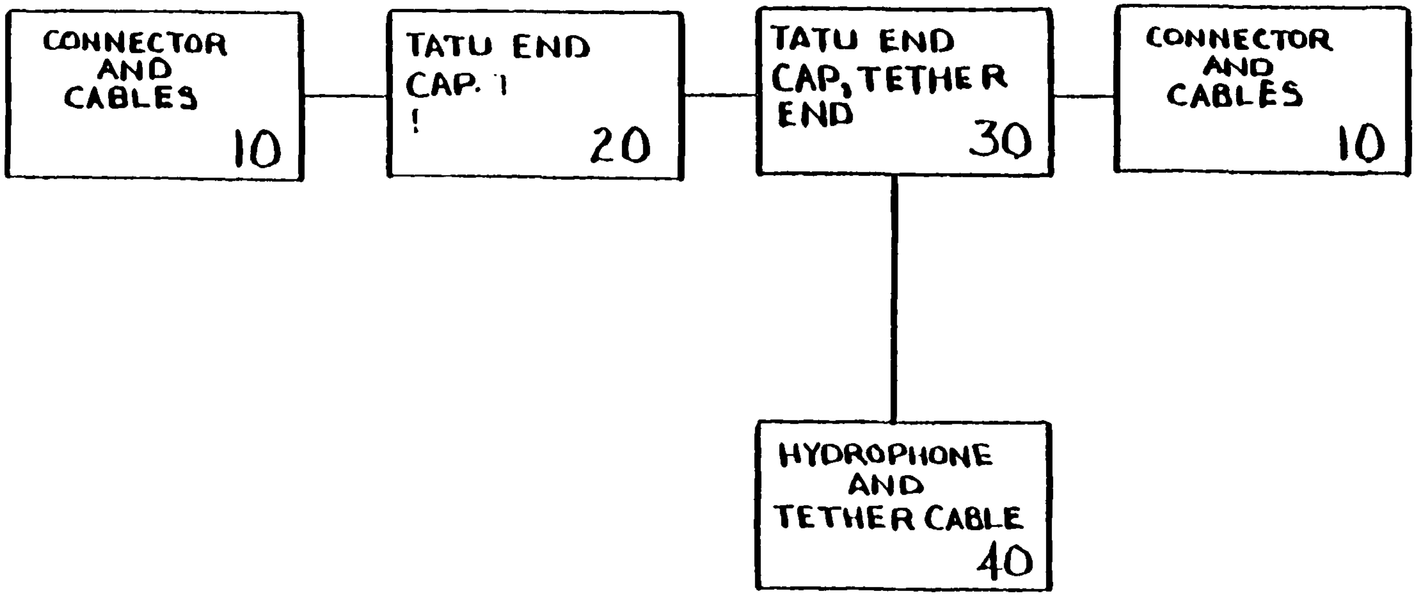



APPENDIX

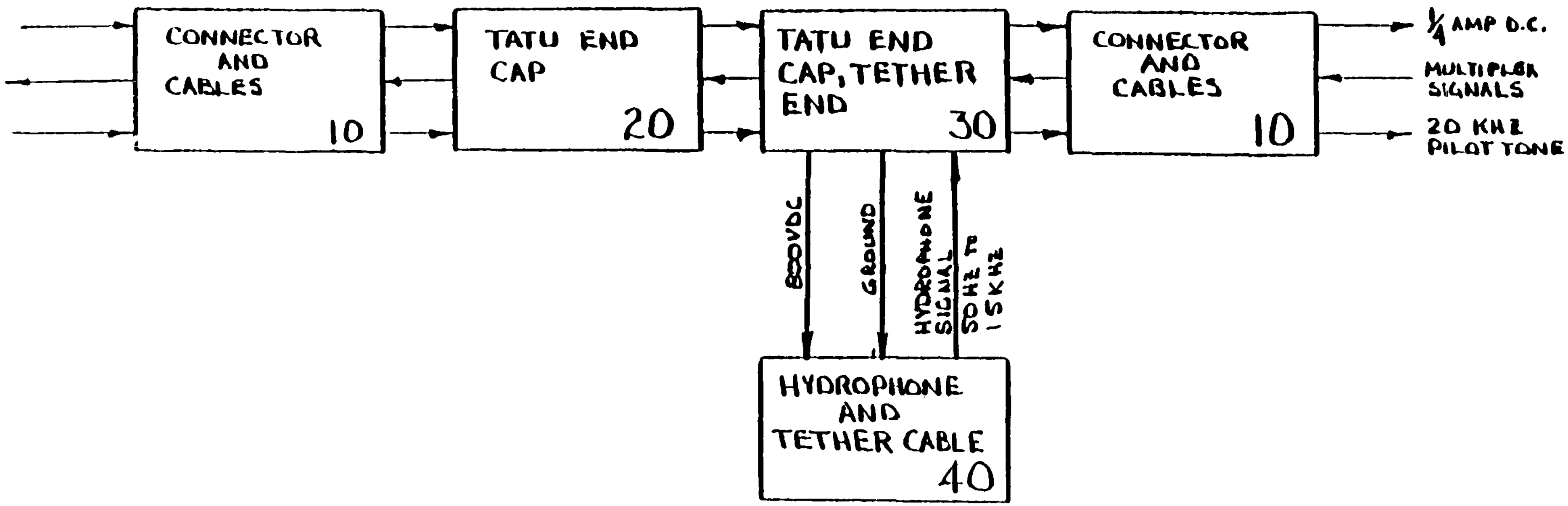
B

FAILURE MODES AND EFFECTS ANALYSIS
WITH
RELIABILITY BLOCK DIAGRAMS

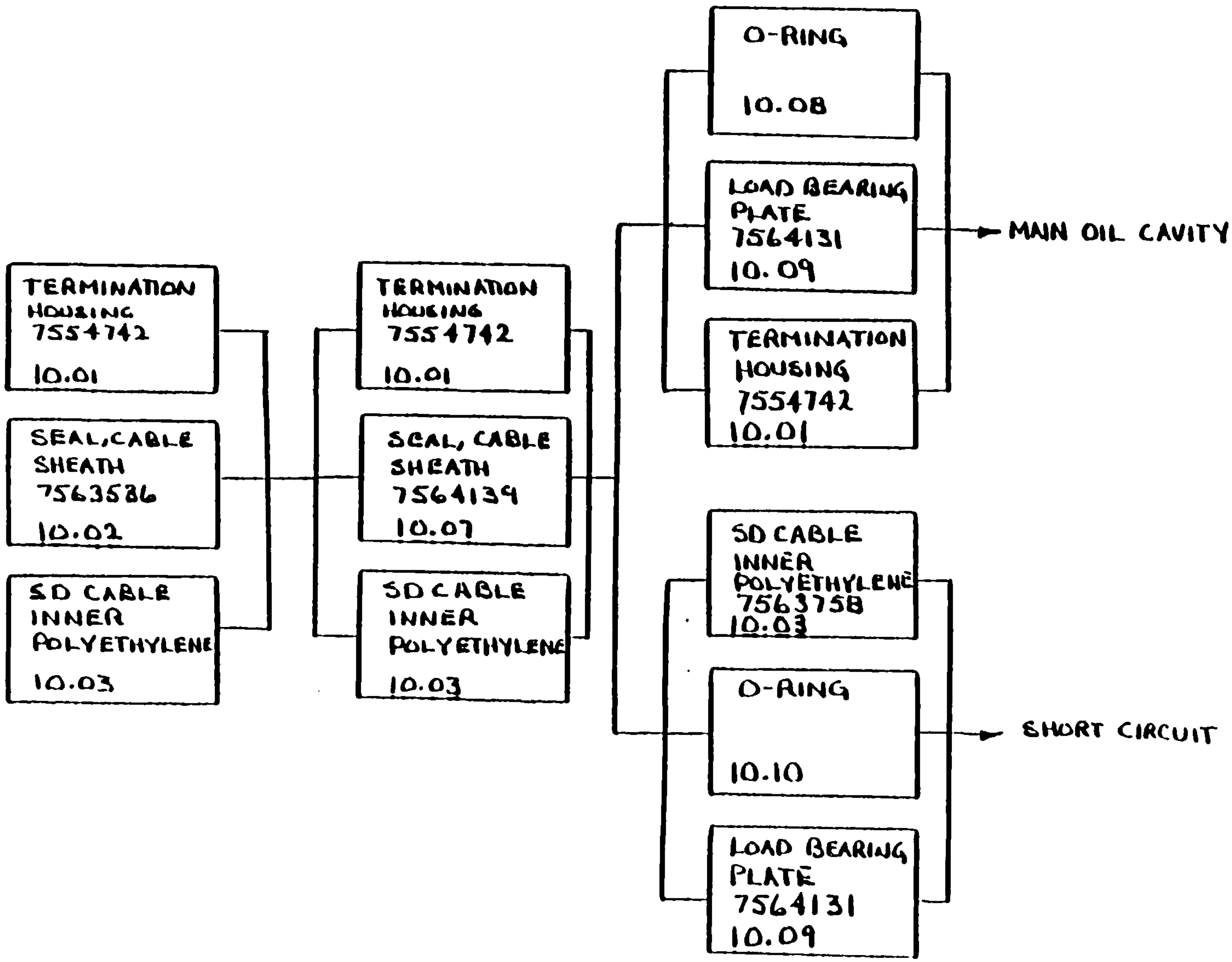
SYSTEM RELIABILITY BLOCK DIAGRAM



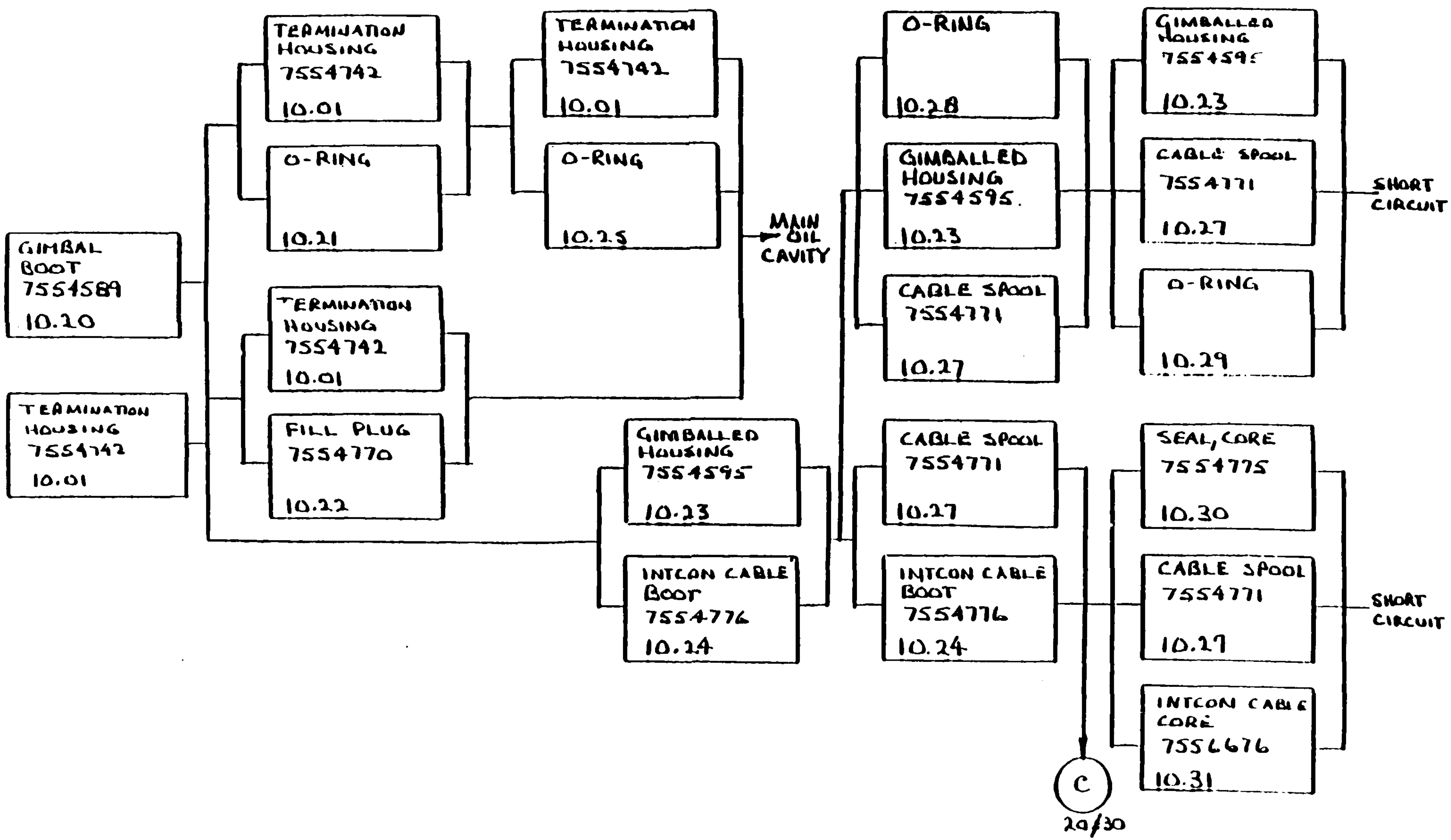
System Functional Block Diagram



10-Connector with Cables — Reliability Block Diagram

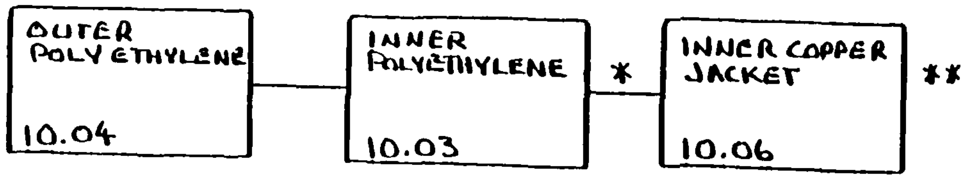


# 10-CONNECTOR WITH CABLES — RELIABILITY BLOCK DIAGRAM



10-CONNECTOR WITH CABLES — RELIABILITY BLOCK DIAGRAM

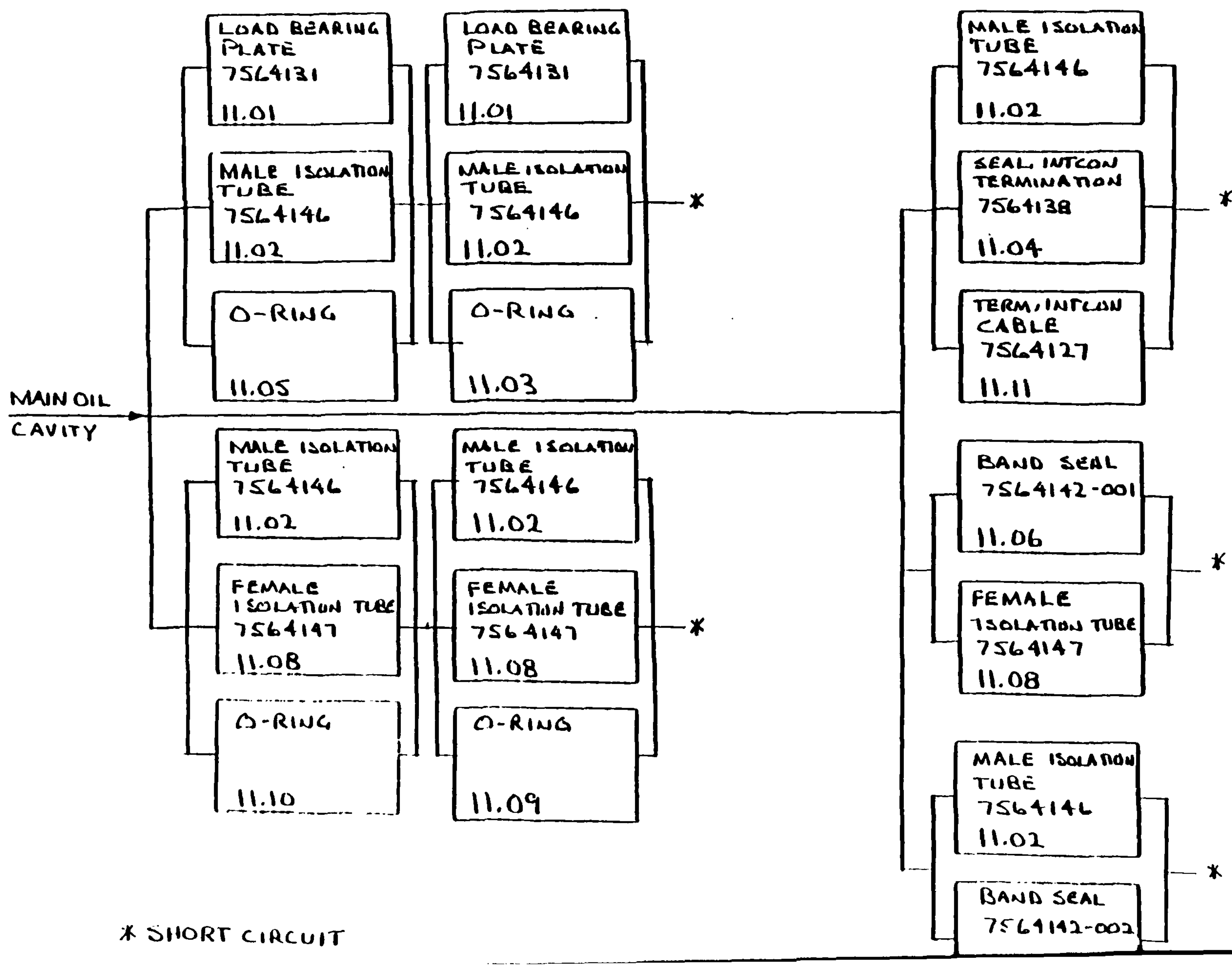
SD CABLE SECTION - 7557344




* SHORT CIRCUIT ESTABLISHED TO SEA WATER

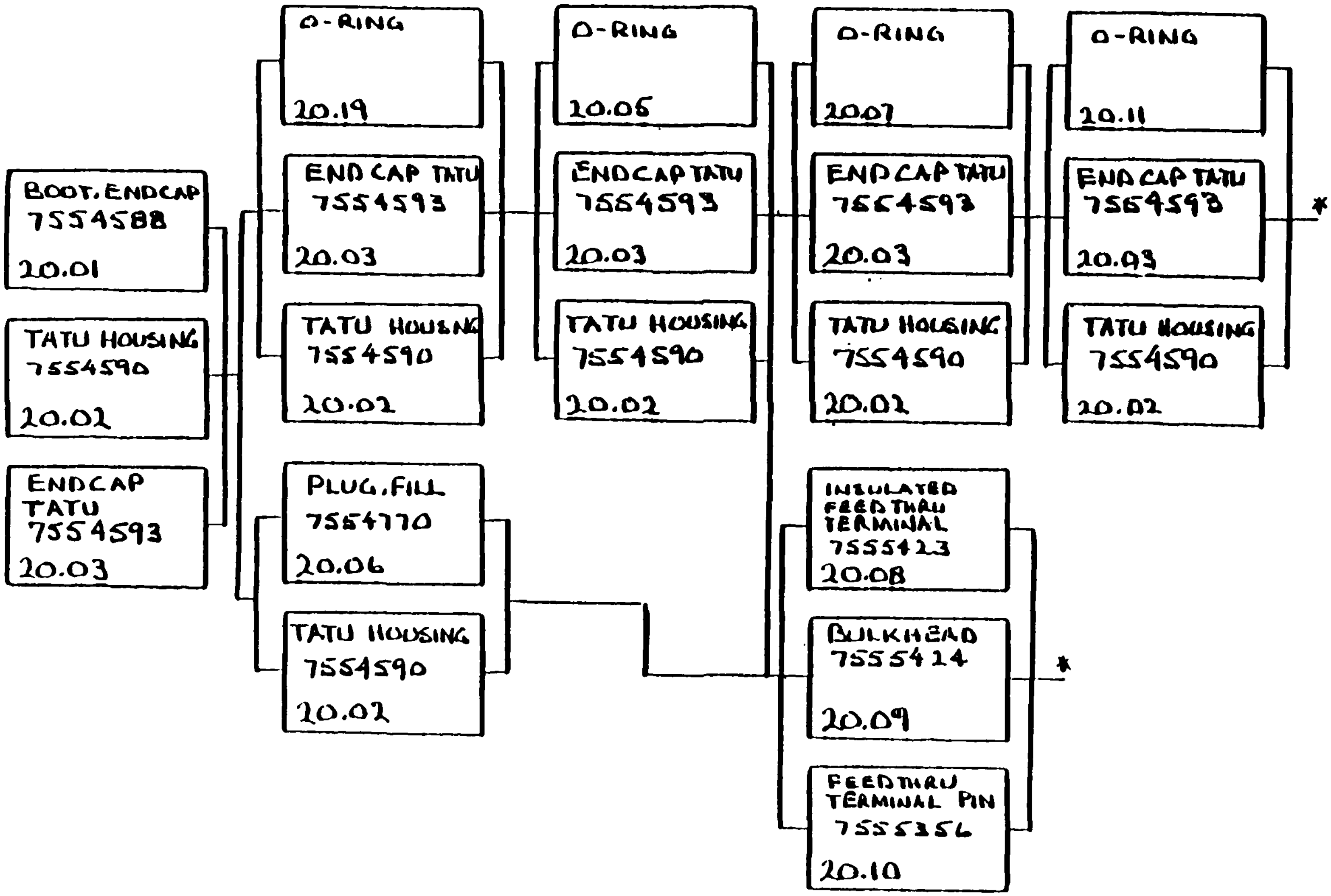
** FULL AMBIENT PRESSURE ON INSIDE OF CABLE

# 11 -Connector with Cables — Reliability Block Diagram



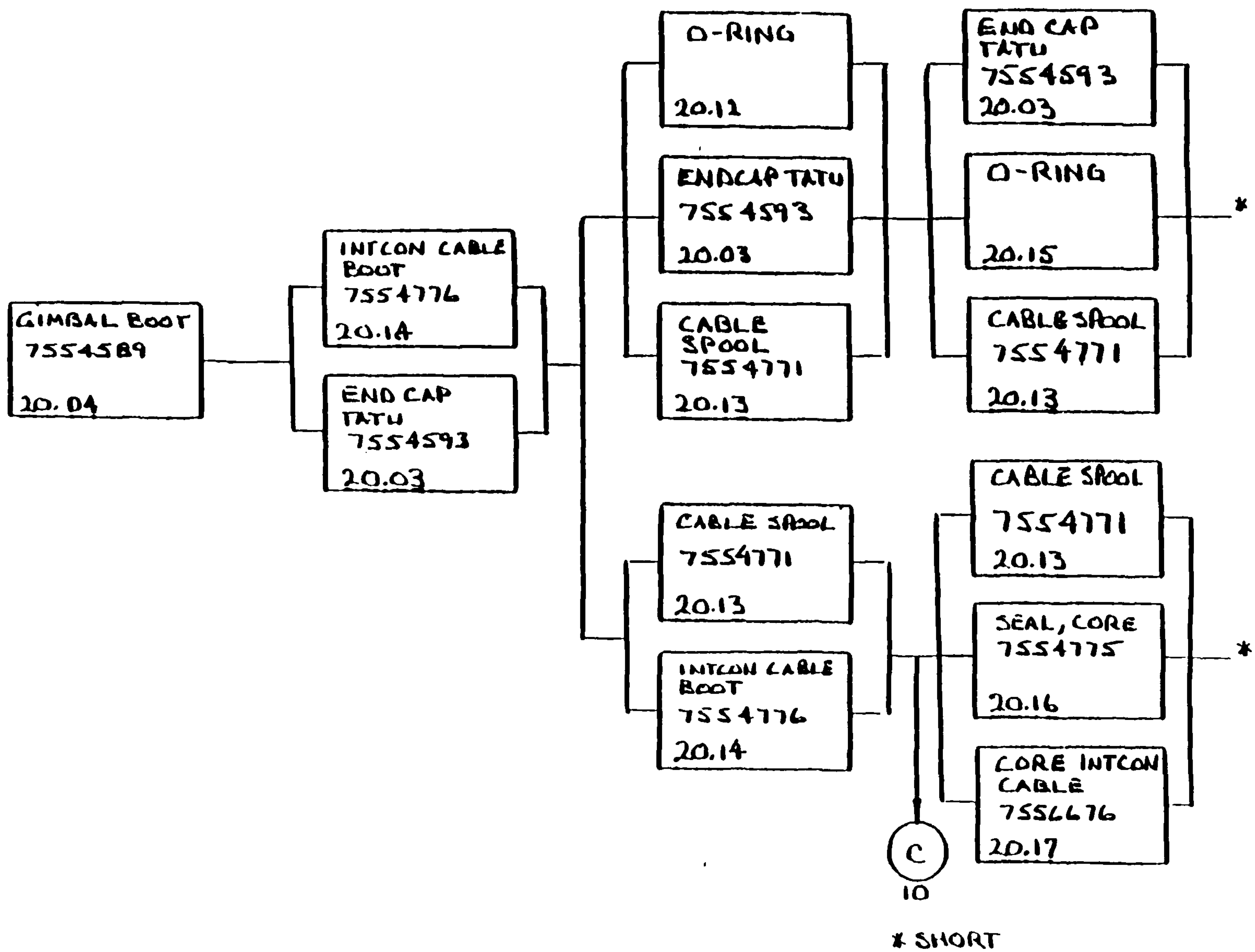

* SHORT CIRCUIT

# 20-TATU END CAP, RELIABILITY BLOCK DIAGRAM

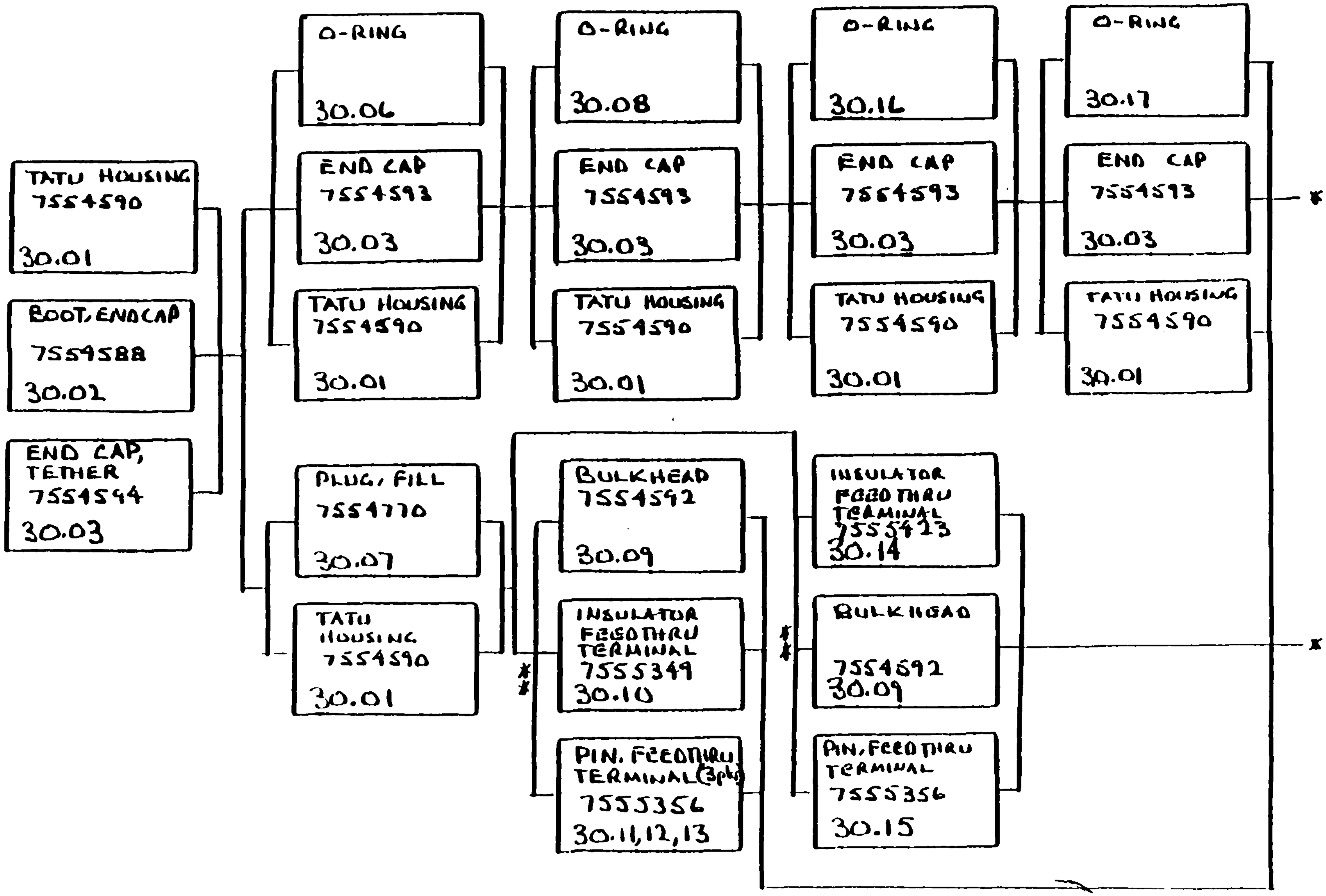



* SHORT

# 20 - TATU END CAP, RELIABILITY BLOCK DIAGRAM

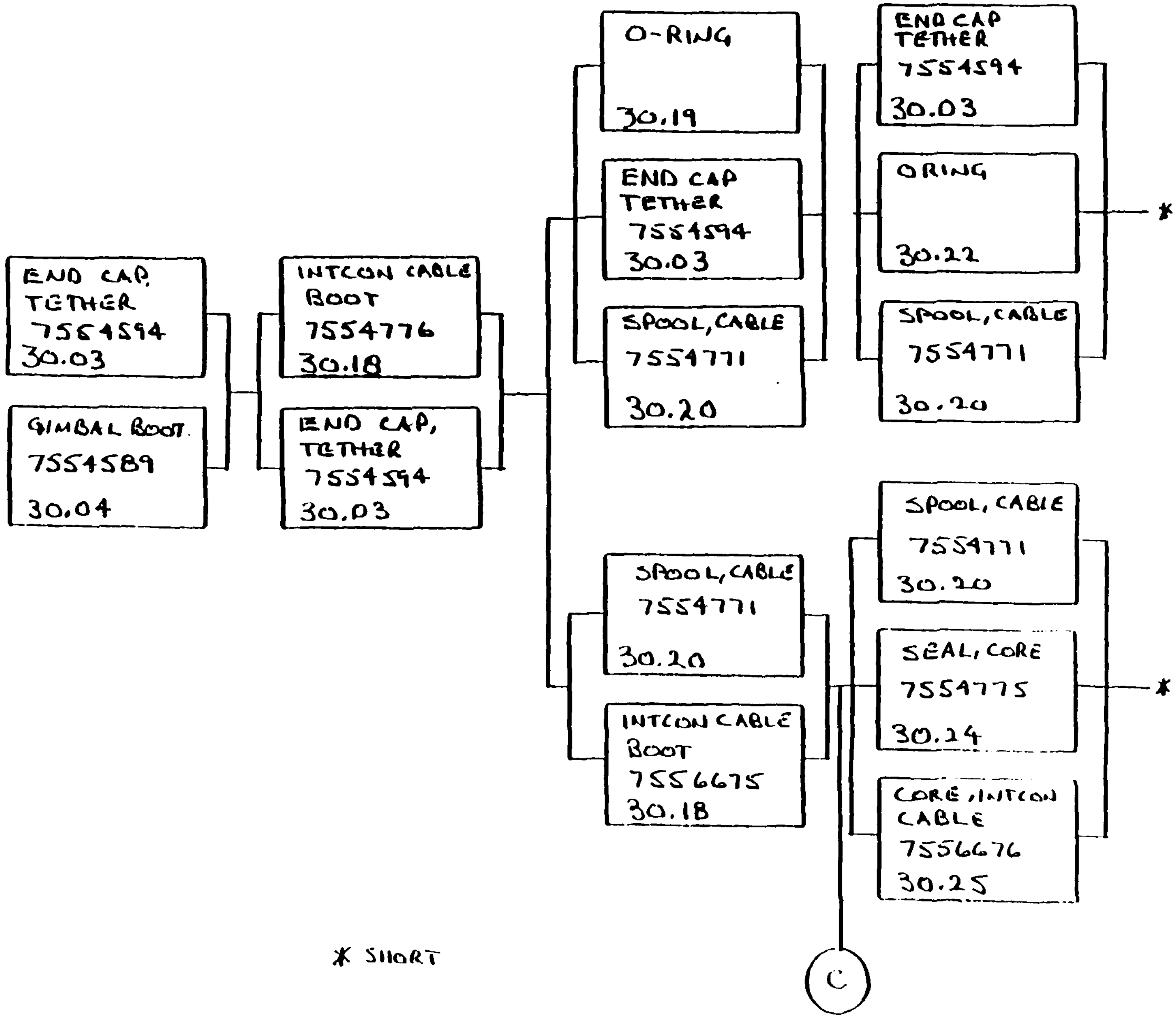


# 30-TATU END CAP, TETHER END— RELIABILITY BLOCK DIAGRAM



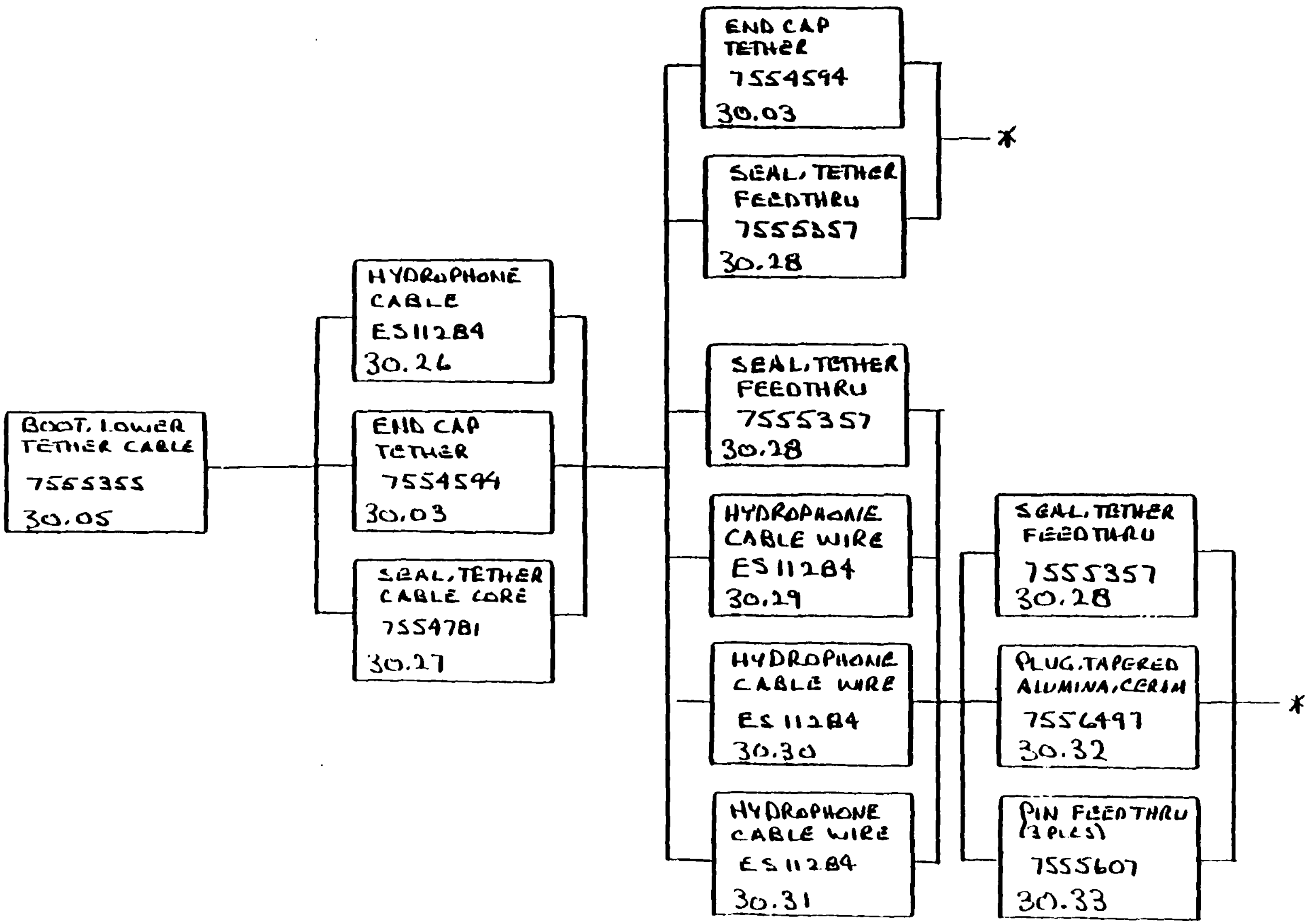

* SHORT CIRCUIT
** POSSIBLE SHORT CIRCUIT

# 30-TATU END CAP, TETHER END— RELIABILITY BLOCK DIAGRAM



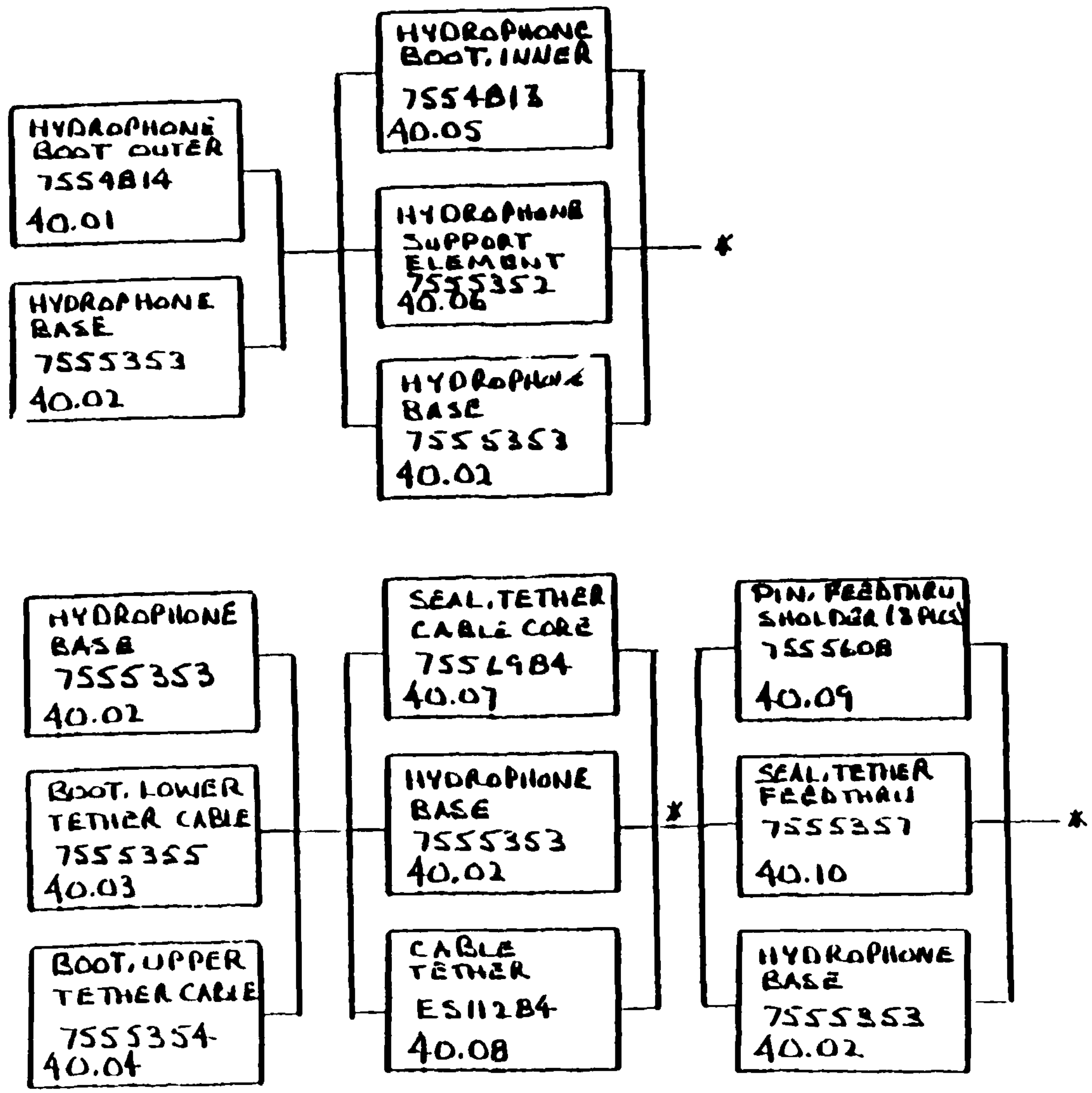

* SHORT

30-TATU END CAP, TETHER END— RELIABILITY BLOCK DIAGRAM




* POSSIBLE SHORT

40-HYDROPHONE AND TETHER CABLE - RELIABILITY BLOCK DIAGRAM




* POSSIBLE SHORT, OIL FILLED AND PRESSURE BALANCED

Subsystem: TATU Assembly
Indenture Level: One
Ref. Drawing: 7356615

ESURE TUTU
FAILURE MODES AND EFFECTS ANALYSIS
IN WATER SEALS

Date: 2 Oct 81
Sheet 1 of 1

| IDENTIFICATION NUMBER | ITEM NAME AND FUNCTION | FAILURE MODE | LOCAL EFFECT | END EFFECT | REMARKS |
|---|---|---|---|---|---|
| 10 | Connector and Cables: Connects SDL1 cable to TATU and then carries mechanical installation loads, hydrophone signals, pilot tone and shore power | Short to sea water | Short hydrophone signals and shore power to sea water | Loss of all hydrophones outboard of this connection | In the event that all TATUS outboard of this connector are lost, the TATU will act as an anode for an indeterminate length of time, then it will fail open causing all TATUS in the string to cease operation. |
| | | OPEN | Hydrophone signals and shore power lost | All TATUS in this string inoperative | |
| | | Mechanical Break | Flooding of connector | Loss of all hydrophones outboard of this connector | |
| 20 | TATU End Cap: holds gimbal end of connector, carries mechanical installation loads, hydrophone signals, pilot tone and shore power | Short to sea water | Short hydrophone signals and shore power to sea water. Apply pressure to 20.8, 20.9, and 20.10 | Loss of all hydrophones outboard of this connection | |
| | | OPEN | Hydrophone signals and shore power lost | All TATUS in this string inoperative | |
| | | Mechanical Break | Flooding of end cap. Apply pressure to 20.8, 20.9, and 20.10 | Loss of all hydrophones outboard of this connector | |
| 30 | TATU End Cap, Tether End: holds gimbal end of connector, carries mechanical installation loads, hydrophone signals, pilot tone and shore power. Also holds the hydrophone tether cable provides power to the hydrophone and conducts the acoustic signals from the hydrophone | Short to sea water | Shorts hydrophone signals and shore power to sea water. Apply pressure to 30.09, 30.10, 30.11, 30.12, 30.13, 30.14, and 30.15 | Loss of all hydrophones outboard of this connection | In the event that all TATUS outboard of this connector are lost, the TATUS will act as an anode for an indeterminate length of time, then it will fail open causing all TATUS in the string to cease operation. |
| | | OPEN | Hydrophone signals and shore power lost | All TATUS in this string inoperative | |
| | | Mechanical Break | Flooding of end cap. Apply pressure to 30.09, 30.10, 30.11, 30.12, 30.13, 30.14, and 30.15 | Loss of all hydrophones outboard of this connector | |
| 40 | Hydrophone and Tether Cable: gathers acoustic signals and sends them to the TATU electronics | Hydrophone tether break (short to sea water or mechanical break) | Loss of individual hydrophone | Degradation of tracking solution in area of lost hydrophone, no effect on other hydrophones | Fuses will blow disconnecting this TATU from the broken hydrophone. The remainder of the TATUS will continue to work. |
| | | OPEN | Loss of individual hydrophone | Degradation of tracking solution in area of lost hydrophone, no effect on other hydrophones | |

Subsystem: Connector with Cables
Indenture Level: Two
Ref. Drawing: 7587344

ESURE TUTU
FAILURE MODES AND EFFECTS ANALYSIS
IN WATER SEALS

Date: 1 Oct 81
Sheet 1 of 1

| IDENTIFICATION NUMBER | ITEM NAME AND FUNCTION | FAILURE MODE | LOCAL EFFECT | END EFFECT | REMARKS |
|---|---|---|---|---|---|
| 10.06 | Inner Copper Jacket: carries voltage and signals | Leakage | Copper and steel corrode | Will result in weakening the cable making two recovery attempts necessary | Full ambient pre on inside of cab will pressure ba seals in termina on both ends of section |
| 10.03 | Inner Polyethylene 7583758 | Leakage | Will short out signal and power | All TATU outboard of the break will not operate | |
| 10.04 | SD Cable Outer Polyethylene | Leakage | Will allow sea water to ground tape and to 10.03 | None | The outer copper corrode slightly will not affect system operation |
| 10.31 | Core, Interconnect Cable 7584676 | Leakage at 10.30 | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these seal are in oil and pr sure balanced. I would be very dif cult to displace oil with sea wate |
| 10.30 | Seal, Core 7584775 | Leakage at 10.27 or 10.31 | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these seal are in oil and pr sure balanced. I would be very dif cult to displace oil with sea wate |
| 10.27 | Seal, Cable 7584771 | Leakage at 10.29 or 10.30 | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these seals are in oil and pr sure balanced. It would be very diff cult to displace oil with sea water |
| 10.29 | O-Ring | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these seals are in oil and pr sure balanced. It would be very diff cult to displace oil with sea water |
| 10.23 | Gimballed Housing 7584995 | Leakage at 10.29 | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these seals are in oil and pre sure balanced. It would be very diff cult to displace t oil with sea water |
| 10.24 | Intcon Cable Boot 7584776 | Leakage at 10.27 | Allow water to 10.30 | None | |
| 10.27 | Seal, Cable 7584771 | Leakage at 10.24 | Allow water to 10.30 | None | |
| 10.23 | Gimballed Housing 7584995 | Leakage at 10.28 | Allow water to 10.29 | None | |
| 10.28 | O-Ring | Leakage at 10.23 | Allow water to 10.29 | None | |
| 10.24 | Intcon Cable Boot 7584776 | Leakage at 10.23 | Allow water to 10.28 and 10.27 | None | |
| 10.23 | Gimballed Housing 7584995 | Leakage at 10.24 | Allow water to 10.28 and 10.27 | None | |
| 10.22 | Fill Plug 7584770 | Leakage | Allow water to main oil cavity of connector | None | |
| 10.25 | O-Ring | Leakage at 10.01 | Allow water to main oil cavity of connector | None | |
| 10.01 | Termination Housing 7584742 | Leakage at 10.25 | Allow water to main oil cavity of connector | None | |

Subsystem: Connector with Cables
Indenture Level: Two
Ref. Drawing: 7556615

ISURE TUTU
FAILURE MODES AND EFFECTS ANALYSIS
IN WATER SEALS

Date: 1 Oct 8[illegible]
Sheet 2 of 2

| IDENTIFICATION NUMBER | ITEM NAME AND FUNCTION | FAILURE MODE | LOCAL EFFECT | END EFFECT | REMARKS |
|---|---|---|---|---|---|
| 10.21 | O-Ring | Leakage at 10.01 | Allow water to 10.25 | None | |
| 10.01 | Termination Housing 7554742 | Leakage at 10.21 | Allow water to 10.25 | None | |
| 10.20 | Gimbal Boot 7554580 | Leakage at 10.01 | Allow water to 10.21, 10.22, and 10.24 | None | |
| 10.20 | Gimbal Boot 7554580 | Hole or Tear | Allow water to 10.21, 10.22, and 10.24 | None | |
| 10.03 | SD Cable Inner Polyethylene 7536758 | Leakage at 10.02 | Allow water to 10.07 | Water | |
| 10.02 | Seal, Cable Sheath 7563836 | Leakage at 10.03 or 10.01 | Allow water to 10.07 | None | |
| 10.01 | Termination Housing 7554742 | Leakage at 10.02 | Allow water to 10.07 | None | |
| 10.02 | SD Cable Inner Polyethylene 7563758 | Leakage at 10.07 | Allow water to 10.08 and 10.10 | None | |
| 10.07 | Seal, Cable Sheath 7564139 | Leakage at 10.03 or 10.01 | Allow water to 10.08 and 10.10 | None | |
| 10.01 | Termination Housing 7554742 | Leakage at 10.07 | Allow water to 10.08 and 10.10 | None | |
| 10.09 | Load Bearing Plate 7564131 | Leakage at 10.10 | Short signal and shore power to sea water | Loss of all TATUS outboard of this connection | |
| 10.10 | O-Ring | Leakage | Short signal and shore power to sea water | Loss of all TATUS outboard of this connection | |
| 10.03 | SD Cable Inner Polyethylene 7563758 | Leakage at 10.10 | Short signal and shore power to sea water | Loss of all TATUS outboard of this connection | |
| 10.01 | Termination Housing 7554742 | Leakage at 10.08 | Allow water to main oil cavity of connector | None | |
| 10.09 | Load Bearing Plate 7564131 | Leakage at 10.08 | Allow water to main oil cavity of connector | None | |
| 10.08 | O-Ring | Leakage at 10.01 or 10.09 | Allow water to main oil cavity of connector | None | |

Subsystem: Connector Main Oil Cavity
Indenture Level: Three
Ref. Drawing: 7556615

SSURE TUTU
FAILURE MODES AND EFFECTS ANALYSIS
IN WATER SEALS

Date: 2 Oct 81
Sheet 1 of 1

| IDENTIFICATION NUMBER | ITEM NAME AND FUNCTION | FAILURE MODE | LOCAL EFFECT | END EFFECT | REMARKS |
|---|---|---|---|---|---|
| 11.10 | O-Ring | Leakage | Allow water to 11.09 | None | |
| 11.08 | Female Isolation Tube 7564147 | Leakage at 11.10 | Allow water to 11.09 | None | |
| 11.02 | Male Isolation Tube 7564146 | Leakage at 11.10 | Allow water to 11.09 | None | |
| 11.09 | O-Ring | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these sea<br>are in oil and p<br>sure balanced.<br>would be very di<br>cult to displace<br>oil with sea wat |
| 11.08 | Female Isolation Tube 7564147 | Leakage at 11.09 | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these sea<br>are in oil and p<br>sure balanced.<br>would be very di<br>cult to displace<br>oil with sea wat |
| 11.02 | Male Isolation Tube 7564146 | Leakage at 11.09 | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these sea<br>are in oil and p<br>sure balanced.<br>would be very di<br>cult to displace<br>oil with sea wat |
| 11.07 | Bond Seal 7564142-001 | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these sea<br>are in oil and p<br>sure balanced.<br>would be very di<br>cult to displace<br>oil with sea wat |
| 11.02 | Male Isolation Tube 7564146 | Leakage at 11.07 or 11.04 | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these seal<br>are in oil and p<br>sure balanced. I<br>would be very di<br>cult to displace<br>oil with sea wat |
| 11.04 | Seal, Intcom Termination | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these seal<br>are in oil and p<br>sure balanced. I<br>would be very di<br>cult to displace<br>oil with sea wat |
| 11.11 | Terminal Intcom Cable 7564127 | Leakage at 11.04 | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these seal<br>are in oil and p<br>sure balanced. I<br>would be very di<br>cult to displace<br>oil with sea wat |
| 11.06 | Bond Seal 7564142-002 | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | These seals are i<br>oil and pressure<br>balanced. It wou<br>be very difficult<br>displace the oil<br>sea water |
| 11.08 | Female Isolation Tube 7564147 | Leakage at 11.06 | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | These seals are i<br>oil and pressure<br>balanced. It wou<br>be very difficult<br>displace the oil<br>sea water |
| 11.05 | O-Ring | Leakage | Allow water to 11.03 | None | |
| 11.01 | Load Bearing Plate 7564131 | Leakage at 11.05 | Allow water to 11.03 | None | |
| 11.08 | Female Isolation Tube 7564147 | Leakage at 11.05 | Allow water to 11.03 | None | |
| 11.03 | O-Ring | Leakage | Short signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these seal<br>are in oil and pr<br>sure balanced. I<br>would be difficul<br>to displace the o<br>with sea water |

Subsystem: TATU End Cap
Indenture Level: Two
Ref. Drawing: 7556619

ESURE TUTU
FAILURE MODES AND EFFECTS ANALYSIS
IN WATER SEALS

Date: 1 Oct 8
Sheet 1 of 2

| IDENTIFICATION NUMBER | ITEM NAME AND FUNCTION | FAILURE MODE | LOCAL EFFECT | END EFFECT | REMARKS |
|---|---|---|---|---|---|
| 20.17 | Core Interconnect Cable 7556676 | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these s are in oil and sure balanced. would be very cult to displa oil with sea w |
| 20.16 | Seal, Core 7554773 | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these s are in oil and sure balanced. would be very cult to displa oil with sea w |
| 20.13 | Inner Cable Seal 7554771 | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these s are in oil and sure balanced. would be very cult to displa oil with sea w |
| 20.15 | O-Ring | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these s are in oil and sure balanced. would be very cult to displa oil with sea w |
| 20.03 | End Cap, TATU 7554688 | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these s are in oil and sure balanced. would be very cult to displa oil with sea w |
| 20.14 | Intercon Cable Boot 7554776 | Leakage | Allow water to 20.16 | None | |
| 20.13 | Seal, Cable 7554771 | Leakage | Allow water to 20.16 or 20.15 | None | |
| 20.03 | End Cap, TATU 7554688 | Leakage | Allow water to 20.15 | None | |
| 20.12 | O-Ring | Leakage | Allow water to 20.15 | None | |
| 20.18 | Intercon Cable Boot 7554776 | Hole or Tear | Allow water to 20.16 | None | |
| 20.18 | Intercon Cable Boot 7554776 | Leakage | Allow water to 20.12 | None | |
| 20.03 | End Cap TATU | Leakage | Allow water to 20.12 | None | |
| 20.04 | Gimbal Boot 7554689 | Leakage | Allow water to 20.18 and fill plug 7554595 | None | |
| 20.02 | TATU Housing 7554698 | Leakage by 20.11 | Allow water into electronics | Loss of all TATUS outboard of this TATU | |
| 20.03 | End Cap TATU 7554688 | Leakage by 20.11 | Allow water into electronics | Loss of all TATUS outboard of this TATU | |
| 20.11 | O-Ring | Leakage | Allow water into electronics | Loss of all TATUS outboard of this TATU | |
| 20.10 | Feed Thru Terminal Pin 7556356 | Leakage by 20.08 | Allow water into electronics | Loss of all TATUS outboard of this TATU | It is very unli that water woul reach this area the cavity woul become pressure balanced when 3 of water had in This level of w would not reach pin or ceramic |
| 20.09 | Bulkhead 7555424 | Leakage by 20.08 | Allow water into electronics | Loss of all TATUS outboard of this TATU | It is very unli that water woul reach this area the cavity woul become pressure balanced when 3 of water had in This level of w would not reach pin or ceramic |

Subsystem: TATU End Cap
Indenture Level: Two
Ref. Drawing: 7556619

ESURE TUTU
FAILURE MODES AND EFFECTS ANALYSIS
IN WATER SEALS

Date: 1 Oct 81
Sheet 2 of 2

| IDENTIFICATION NUMBER | ITEM NAME AND FUNCTION | FAILURE MODE | LOCAL EFFECT | END EFFECT | REMARKS |
|---|---|---|---|---|---|
| 20.08 | Insulated Feed Thru Terminal, 7558423 | Leakage by 20.09, 20.10 | Allow water into electronics | Loss of all TATUS outboard of this TATU | It is very unlike[ly] that water would reach this area a[s] the cavity would become pressure balanced when 10 [...] of water has intr[uded]. This level of wat[er] would not reach t[he] pin or ceramic |
| 20.02 | TATU Housing 7554680 | Leakage by 20.07 | Allow water to 20.11 | None | |
| 20.03 | End Cap, TATU | Leakage by 20.07 | Allow water to 20.11 | None | |
| 20.07 | O-Ring | Leakage | Allow water to 20.11 | None | |
| 20.02 | TATU Housing 7554680 | Leakage by 20.05 | Allow water to 20.07 | None | |
| 20.03 | End Cap, TATU 7554683 | Leakage by 20.05 | Allow water to 20.07 | None | |
| 20.05 | O-Ring | Leakage | Allow water to 20.07 | None | |
| 20.02 | TATU Housing 7554690 | Leakage by 20.06 | Allow water to 20.07 | None | |
| 20.06 | Plug, Fill 7554770 | Leakage | Allow water to 20.07 | None | |

Subsystem: TATU End Cap, Tether End
Indenture Level: Two
Ref. Drawing: 7386618

SSURE TUTU
FAILURE MODES AND EFFECTS ANALYSIS
IN WATER SEALS

Date: 28 Sep 83
Sheet 1 of 2

| IDENTIFICATION NUMBER | ITEM NAME AND FUNCTION | FAILURE MODE | LOCAL EFFECT | END EFFECT | REMARKS |
|---|---|---|---|---|---|
| 30.33-1 | Pin, Feed Thru: Feeds Electrical Signal from Tether Cable to TATU Electronics | Leakage | Short hydrophone signal to sea water, allow sea water into cavity between bulkheads | Loss of signal from hydrophone, possible shorting of TATU electronics | The space between bulkheads of the will equalize pressure before enough water gathers to short out the TATU electronics |
| 30.33-2 | Pin, Feed Thru: Feeds Voltage to the Hydrophone | Leakage | Short voltage to sea water, allow water into cavity between bulkheads | Loss of signal from hydrophone, possible shorting of TATU electronics | The space between bulkheads of the will equalize pressure before enough water gathers to short out the TATU electronics |
| 30.33-3 | Pin, Feed Thru: Ground for Voltage to Hydrophone | Leakage | Allow water into cavity between bulkheads | Possible shorting of TATU electronics | The space between bulkheads of the will equalize pressure before enough water gathers to short out the TATU electronics |
| 30.28 | Seal, Tether Feed Thru | Leakage at ceramic plug (30.32) | Allow water into cavity between bulkheads | Possible shorting of TATU electronics | The space between bulkheads of the will equalize pressure before enough water gathers to short out the TATU electronics |
| 30.28 | Seal, Tether Feed Thru | Leakage at feed thru pins | See 30.33-1, -2, -3 above | See 30.33-1, -2, -3 above | The space between bulkheads of the T will equalize pressure before enough water gathers to short out the TATU electronics |
| 30.31 | Hydrophone Cable, Wire: Ground for Voltage to Hydrophone | Leakage | Allow sea water to feed thru pin 30.33-3 | None | Water in the cable wires implys a cut the wires and cable with water in hydrophone also see 40. |
| 30.30 | Hydrophone Cable, Wire: Feeds Voltage to the Hydrophone | Leakage | Short voltage to sea water, allow sea water to feed thru pin 30.33-2 | Loss of signal from hydrophone | Water in the cable wires implys a cut the wires and cable with water in hydrophone also see 40. |
| 30.29 | Hydrophone Cable, Wire: Feeds Electrical Signal from Tether Cable to TATU Electronics | Leakage | Short hydrophone signal to sea water, allow sea water to feed thru pin 30.33-1 | Loss of signal from hydrophone | Water in the cable wires implys a cut the wires and cable with water in hydrophone also see 40. |
| 30.28 | Seal, Tether Feed Thru | Leakage at feed thru pins | See 30.29, 30.30, and 30.31 above | See 30.29, 30.30, and 30.31 above | |
| 30.28 | Seal, Tether Feed Thru | Leakage at end cap | Allow water into cavity between bulkheads | Possible shorting of TATU electronics | The space between bulkheads of the TA will equalize pressure before enough water gathers to short out the TATU electronics |
| 30.03 | End Cap, Tether End | Leakage at seal (30.28) | Allow water into cavity between bulkheads | Possible shorting of TATU electronics | The space between bulkheads of the TA will equalize pressure before enough water gathers to short out the TATU electronics |
| 30.27 | Seal, Tether Cable Core | Leakage | Allow water to tether feed thru seal (30.28) | None | Oil would first be pressurized to 7,50 psi before water could reach seal 30.28. Chances of water reaching that seal would be small |
| 30.26 | Hydrophone Cable | Leakage | Allow water to tether feed thru seal (30.28) | None | |

Subsystem: TATU End Cap, Tether End
Indenture Level: Two
Ref. Drawing: 7566618

BSURE TUTU
FAILURE MODES AND EFFECTS ANALYSIS
IN WATER SEALS

Date: 28 Sep 81
Sheet 2 of 3

| IDENTIFICATION NUMBER | ITEM NAME AND FUNCTION | FAILURE MODE | LOCAL EFFECT | END EFFECT | REMARKS |
|---|---|---|---|---|---|
| 30.03 | End Cap, Tether End | Leakage at 30.27 | Allow water to tether feed thru seal (30.28) | None | Oil would first be pressurized to 7.5 psi before water could reach seal 30.28. Chances of water reaching the seal would be small |
| 30.05 | Tether Cable Boot | Leakage | Allow water between boot and tether cable | None | This is pressure balanced. The oil would be displaced gradually by gavity action and tidal action |
| 30.25 | Core Interconnect Cable | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these seals are in oil and pressure balanced. It would be very difficult to displace the oil with sea water |
| 30.24 | Seal Core | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these seals are in oil and pressure balanced. It would be very difficult to displace the oil with sea water |
| 30.20 | Spool, Cable | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these seals are in oil and pressure balanced. It would be very difficult to displace the oil with sea water |
| 30.22 | O-Ring | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these seals are in oil and pressure balanced. It would be very difficult to displace the oil with sea water |
| 30.03 | End Cap, Tether | Leakage | Short TATU signal and shore power to sea water | Loss of all TATUS outboard of this connection | All of these seals are in oil and pressure balanced. It would be very difficult to displace the oil with sea water |
| 30.19 | O-Ring | Leakage | Allow water to 30.22 | None | |
| 30.18 | Intcon Cable Boot | Leakage | Allow water to 30.24 | None | |
| 30.20 | Spool, Cable | Leakage | Allow water to 30.22 or 30.24 | None | |
| 30.03 | End Cap, Tether | Leakage | Allow water to 30.22 | None | |
| 30.18 | Intcon Cable Boot | Hole or Tear | Allow water to 30.24 | None | |
| 30.18 | Intcon Cable Boot | Leakage | Allow water to 30.19 | None | |
| 30.03 | End Cap, Tether | Leakage | Allow water to 30.19 | None | |
| 30.04 | Gimbal Boot | Leakage | Allow water to 30.18 and 30.26 | None | |
| 30.04 | Gimbal Boot | Hole or Tear | Allow water to 30.18 and 30.26 | None | |
| 30.03 | End Cap, Tether | Leakage | Allow water to 30.18 and 30.26 | None | |
| 30.01 | TATU Housing | Leakage | Allows water into electronics | Loss of all TATUS outboard of this TATU | |
| 30.03 | End Cap | Leakage | Allows water into electronics | Loss of all TATUS outboard of this TATU | |
| 30.17 | O-Ring | Leakage | Allows water into electronics | Loss of all TATUS outboard of this TATU | |
| 30.15 | Pin, Feed Thru Terminal | Leakage | Allows water into electronics | Loss of all TATUS outboard of this TATU | It is very unlikely that water would reach this area as the cavity would become pressure balanced when 30 cc of water has intruded |

Subsystem: TATU End Cap, Tether End
Indenture Level: Two
Ref. Drawing: 7386618

ASURE TUTU
FAILURE MODES AND EFFECTS ANALYSIS
IN WATER SEALS

Date: 28 Sep 81
Sheet 3 of 3

| IDENTIFICATION NUMBER | ITEM NAME AND FUNCTION | FAILURE MODE | LOCAL EFFECT | END EFFECT | REMARKS |
|---|---|---|---|---|---|
| 30.09 | Bulkhead | Leakage | Allows water into electronics | Loss of all TATUS outboard of this TATU | It is very unlike that water would reach this area the cavity would become pressure balanced when 30 of water has intr |
| 30.14 | Insulator Feed Thru Terminal | Leakage | Allows water into electronics | Loss of all TATUS outboard of this TATU | It is very unlike that water would reach this area a the cavity would become pressure balanced when 30 of water has intr |
| 30.13 | Pin, Feed Thru Terminal | Short leakage | Shorts hydrophone, allows water into electronics | Loss of hydrophone. Loss of all TATUS outboard of this TATU | It is very unlike that water would reach this area a the cavity would become pressure balanced when 30 of water has intr |
| 30.12 | Pin, Feed Thru Terminal | Short leakage | Shorts hydrophone, allows water into electronics | Loss of hydrophone. Loss of all TATUS outboard of this TATU | It is very unlike that water would reach this area as the cavity would become pressure balanced when 30 c of water has intr |
| 30.11 | Pin, Feed Thru Terminal | Leakage | Allows water into electronics | Loss of all TATUS outboard of this TATU | It is very unlike that water would reach this area a the cavity would become pressure balanced when 30 c of water has intr |
| 30.10 | Insulator Feed Thru Terminal | Leakage | Allows water into electronics | Loss of all TATUS outboard of this TATU | It is very unlikel that water would reach this area as the cavity would become pressure balanced when 30 c of water has intru |
| 30.09 | Bulkhead | Leakage | Allows water into electronics | Loss of all TATUS outboard of this TATU | It is very unlikel that water would reach this area as the cavity would become pressure balanced when 30 c of water has intru |
| 30.01 | TATU Housing | Leakage | Allows water to 30.16 | None | |
| 30.03 | End Cap | Leakage | Allows water to 30.16 | None | |
| 30.06 | O-Ring | Leakage | Allows water to 30.16 | None | |
| 30.07 | Plug Fill | Leakage | Allows water to 30.16 | None | |
| 30.01 | TATU Housing | Leakage | Allows water to 30.16 or 30.08 | None | |
| 30.03 | End Cap | Leakage | Allows water to 30.08 | None | |
| 30.06 | O-Ring | Leakage | Allows water to 30.08 | None | |
| 30.01 | TATU Housing | Leakage | Allows water to 30.06 | None | |
| 30.02 | Boot, End Cap | Leakage | Allows water to 30.06 | None | |

Subsystem: Hydrophone and Tether Cable
Indenture Level: Two
Ref. Drawings:

BSURE TUTU
FAILURE MODES AND EFFECTS ANALYSIS
IN WATER SEALS

Date: 24 Sep 81
Sheet 1 of 1

| IDENTIFICATION NUMBER | ITEM NAME AND FUNCTION | FAILURE MODE | LOCAL EFFECT | END EFFECT | REMARKS |
|---|---|---|---|---|---|
| 40.09-1 | Feed Thru Shielded Pins Feeds Electrical Signal from Hydrophone to Tether Cable | Leakage | Short signal to sea water, allow water into hydrophone cavity | Loss of signal from hydrophone | Very unlikely the seal will leak as is pressure balanc Other TATUS in str will still functio |
| 40.09-2 | Feed Thru Shielded Pins Feeds Voltage to Hydrophone | Leakage | Short voltage to sea water, allow water into hydrophone cavity | Loss of signal from hydrophone, blown fuze in TATU | Very unlikely the seal will leak as is pressure balanc Other TATUS in str will still functio |
| 40.09-3 | Feed Thru Shielded Pins Ground for Voltage to Hydrophone | Leakage | Allow water into hydrophone cavity | Depends on quantity of water, a small* amount would have no effect | Very unlikely the seal will leak as is pressure balanc Other TATUS in str will still functio |
| 40.10 | Seal Tether Feed Thru | Leakage | Short out hydrophone, allow water into hydrophone cavity | Loss of signal to hydrophone | Very unlikely the seal will leak as is pressure balanc Other TATUS in str will still functio |
| 40.02 | Hydrophone Base | Leakage or Hole in Base | Allow water into hydrophone cavity | Depends on quantity of water, a small* amount would have no effect | Very unlikely the seal will leak as is pressure balanc Other TATUS in str will still function |
| 40.05 | Inner Hydrophone Boot | Leakage | Allow water into hydrophone cavity | Loss of signal from hydrophone, blown fuze in TATU | Very unlikely the seal will leak as is pressure balanc Other TATUS in str will still function |
| 40.06 | Hydrophone Support Element | Leakage | Allow water into hydrophone cavity | Loss of signal from hydrophone, blown fuze in TATU | Very unlikely the seal will leak as is pressure balanc Other TATUS in str will still function |
| 40.07 | Seal Tether Cable Core | Leakage | Allow water to 40.09 and 40.10 | Possible loss of signal | Very unlikely the seal will leak as is pressure balanc Other TATUS in str will still function |
| | | | | | Loss of signal depends on leak pat |
| 40.02 | Hydrophone Base | Leakage or hole before 40.07 | Allow water to 40.09 and 40.10 | Possible loss of signal | Very unlikely the seal will leak as is pressure balanc Other TATUS in str will still function |
| | | | | | Loss of signal depends on leak pat |
| 40.08 | Cable Tether | Leakage or hole in cable jacket | Allow water to 40.09 and 40.10 | Possible loss of signal | Also allows water t TATU end. |
| | | | | | Cap tether end 30.2 |
| 40.01 | Hydrophone Boot Outer | Leakage | Allow water between inner and outer boot | None | Also allows water to TATU end |
| 40.02 | Hydrophone Basic | Leakage | Allow water between inner and outer boot | None | Also allows water to TATU end |
| 40.03 | Lower Tether Cable Boot | Leakage | Allow water between boot and cable, water on 40.07 | None | Also allows water to TATU end |
| 40.04 | Upper Tether Cable Boot | Leakage | Allow water between boot and cable, water on 40.07 | None | Also allows water to TATU end |

*Less than 40 cc

APPENDIX

C

CROSS INDEX IDENTIFICATION NUMBER
TO
DELCO DRAWING NUMBER

10 - Connector with Cables

| Block Diagram Number | Delco Drawing Number | Nomenclature | Sketch Number |
|---|---|---|---|
| 10.01 | 7554742 | Housing, Termination | 9 |
| 10.02 | 7563536 | Seal, Cable Sheath | 1 |
| 10.03 | 7563758 | SD Cable Inner Polyethylene | 3 |
| 10.04 | 7557344 | SD Cable Outer Polyethylene | 3 |
| 10.05 | | | |
| 10.06 | 7557344 | SD Cable Inner Copper Jacket | 3 |
| 10.07 | 7564139 | Seal, Cable Sheath | 2 |
| 10.08 | | O-Ring | 5 |
| 10.09 | 7564131 | Load Bearing Plate | 6 |
| 10.10 | | O-Ring | 4 |
| 10.11 | | O-Ring | 12 |
| 10.12 | | O-Ring | 13 |
| 10.13 | 7564142-001 | Band Seal | 19 |
| 10.14 | 7564142-002 | Band Seal | 21 |
| 10.15 | 7564147 | Female Isolation Tube | 22 |
| 10.16 | | O-Ring | 23 |
| 10.17 | | O-Ring | 24 |
| 10.18 | 7564146 | Male Isolation Tube | 25 |
| 10.19 | 7564138 | Seal, Intercon Termination | 26 |
| 10.20 | 7554589 | Gimbal Boot | 17 |
| 10.21 | | O-Ring | 16 |
| 10.22 | 7554770 | Fill Plug | 28 |
| 10.23 | 7554595 | Gimballed Housing | 31 |
| 10.24 | 7554776 | Intcon Cable Boot | 35 |
| 10.25 | | O-Ring | 15 |
| 10.26 | 7554595 | Housing, Gimballed | 31 |
| 10.27 | 7554771 | Spool, Cable | 32 |
| 10.28 | | O-Ring | 34 |
| 10.29 | | O-Ring | 33 |
| 10.30 | 7554775 | Seal, Core | 30 |
| 10.31 | 7556676 | Core Intcon Cable | 36 |
| 11.11 | 7564127 | Terminal Intcon Cable | 37 |

## 20 - TATU End Cap

| Block Diagram Number | Delco Drawing Number | Nomenclature | Sketch Number |
|---|---|---|---|
| 20.01 | 7554588 | Boot, End Cap | 6 |
| 20.02 | 7554590 | TATU Housing | 3 |
| 20.03 | 7554593 | End Cap, TATU | 2 |
| 20.04 | 7554589 | Gimbal Boot | 17 |
| 20.05 | | O-Ring | 20 |
| 20.06 | 7554770 | Plug, Fill | 8 |
| 20.07 | | O-Ring | 21 |
| 20.08 | 7555423 | Feed Thru, Terminal | 5 |
| 20.09 | 7555424 | Bulkhead | 4 |
| 20.10 | 7555356 | Feed Thru, Terminal Pin | 9 |
| 20.11 | | O-Ring | 22 |
| 20.12 | | O-Ring | 34 |
| 20.13 | 7554771 | Spool, Cable | 32 |
| 20.14 | 7554776 | Cable, Boot Intcon | 35 |
| 20.15 | | O-Ring | 33 |
| 20.16 | 7554775 | Seal, Core | 30 |
| 20.17 | 7556676 | Core, Intcon Cable | 36 |
| 20.18 | | Blank | |
| 20.19 | | O-Ring | 19 |

## 30 - TATU End Cap, Tether End

| Block Diagram Number | Delco Drawing Number | Nomenclature | Sketch Number |
|---|---|---|---|
| 30.01 | 7554590 | TATU Housing | 3 |
| 30.02 | 7554588 | Boot, End Cap | 6 |
| 30.03 | 7554594 | End Cap Tether | 2 |
| 30.04 | 7554589 | Gimbal Boot | 17 |
| 30.05 | 7555355 | Boot, Lower Tether Cable | 41 |
| 30.06 | | O-Ring | 19 |
| 30.07 | 7554770 | Plug, Fill | 8 |
| 30.08 | | O-Ring | 20 |
| 30.09 | 7554590 | Bulkhead | 4 |
| 30.10 | 7555349 | Feed Thru Terminal Insulator | 13 |
| 30.11 | 7555356 | Pin, Feed Thru Terminal | 14 |
| 30.12 | 7555356 | Pin, Feed Thru Terminal | 15 |
| 30.13 | 7555356 | Pin, Feed Thru Terminal | 16 |
| 30.14 | 7555423 | Insulator, Feed Thru Terminal | 5 |
| 30.15 | 7555356 | Pin, Feed Thru Terminal | 9 |
| 30.16 | | O-Ring | 21 |
| 30.17 | | O-Ring | 22 |
| 30.18 | 7554776 | Intcon Cable Boot | 35 |
| 30.19 | | O-Ring | 34 |
| 30.20 | 7554771 | Spool, Cable | 32 |
| 30.21 | | | |
| 30.22 | | O-Ring | 33 |
| 30.23 | | | |
| 30.24 | 7554775 | Seal, Core | 30 |
| 30.25 | 7556676 | Core Interconnect Cable | 36 |
| 30.26 | ES11281 | Hydrophone Cable | C |
| 30.27 | 7554781 | Seal, Tether Cable Core | 40 |
| 30.28 | 7555357 | Seal Tether Feed Thru | 44 |
| 30.29 | ES11281 | Hydrophone Cable Wire | $C_1$ |
| 30.30 | ES11281 | Hydrophone Cable Wire | $C_2$ |
| 30.31 | ES11281 | Hydrophone Cable Wire | $C_3$ |
| 30.32 | 7556497 | Plug, Tapered Alumina Ceramic | 45 |
| 30.33 | 7555607 | Pin Feed Thru | 46 |

## 40 - Hydrophone and Tether Cable

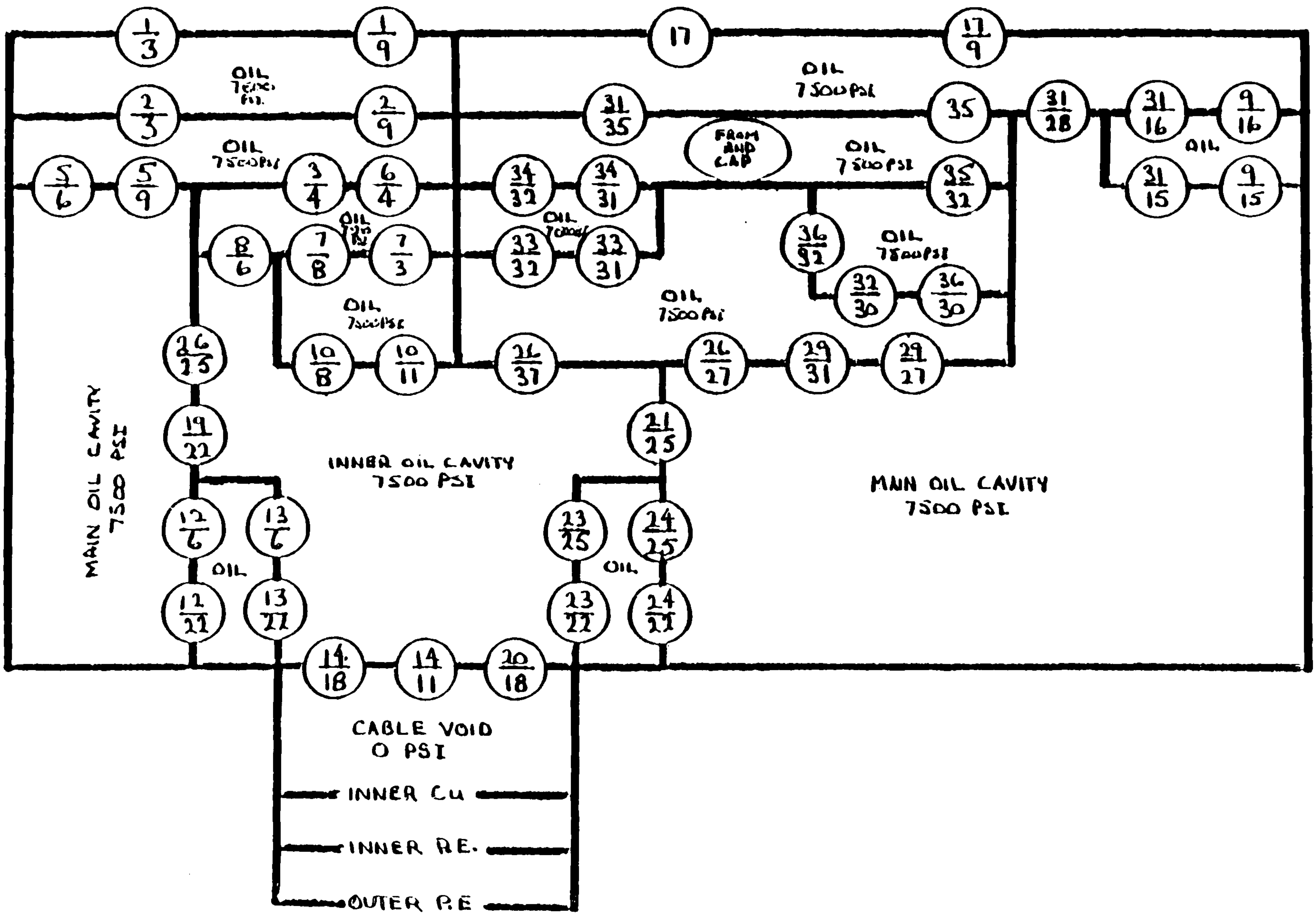
| Block Diagram Number | Delco Drawing Number | Nomenclature | Sketch Number |
|---|---|---|---|
| 40.01 | 7554814 | Hydrophone Boot, Outer | 11 |
| 40.02 | 7555353 | Hydrophone Base | 4 |
| 40.03 | 7555355 | Boot, Lower Tether Cable | 41 |
| 40.04 | 7555354 | Boot, Upper Tether Cable | 51 |
| 40.05 | 7554813 | Hydrophone Boot, Inner | 10 |
| 40.06 | 7555352 | Hydrophone Support Element | 14 |
| 40.07 | 7556984 | Seal, Tether Cable Core | 3 |
| 40.08 | ES11284 | Cable, Tether | C, $C_1$, $C_2$, $C_3$ |
| 40.09 | 7555608 | Pin, Feed Thru, Sholder | 7 |
| 40.10 | 7555357 | Seal Tether Feed Thru | 8 |

# APPENDIX

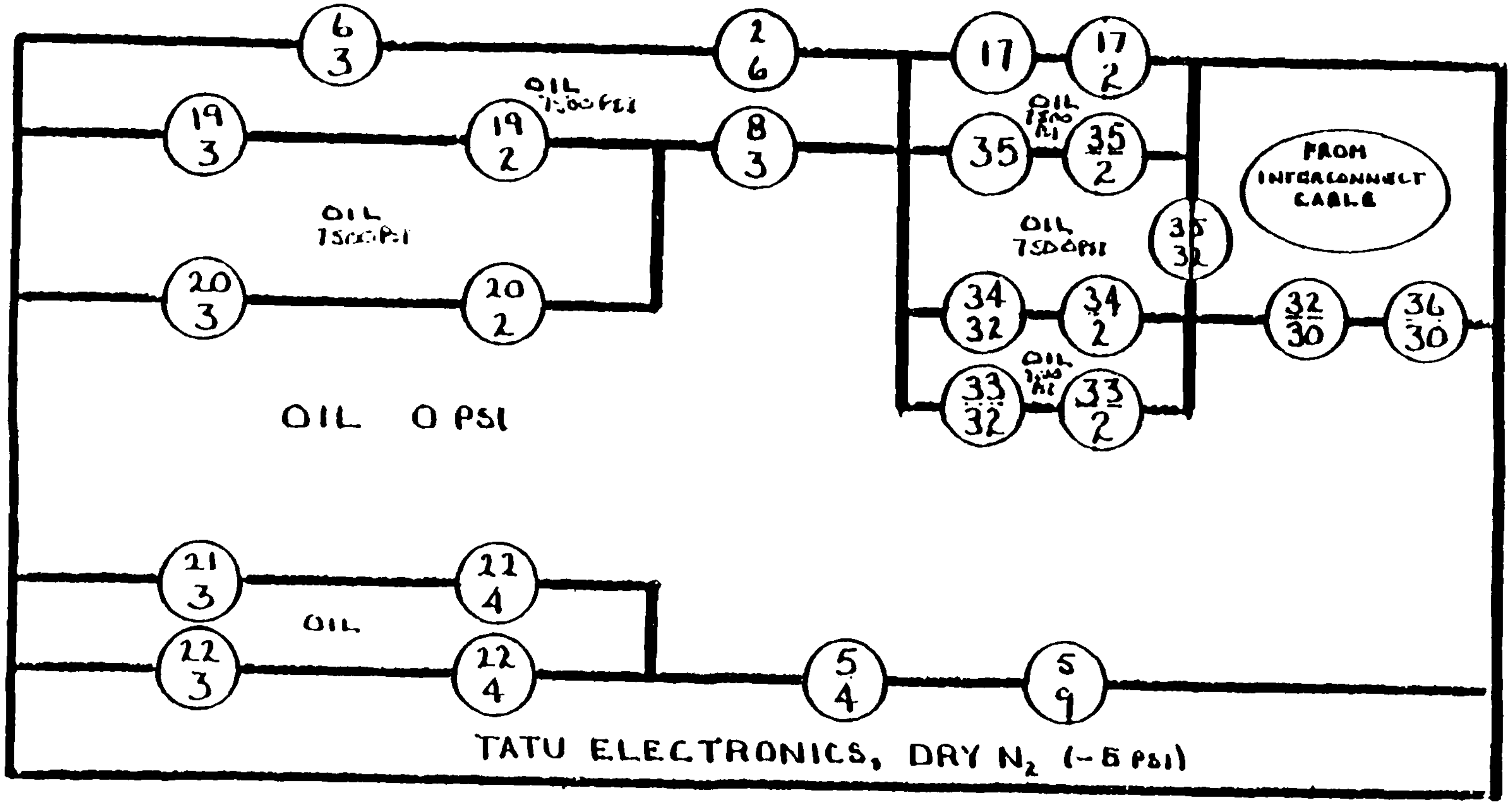
# D

# SEALING SYSTEM BARRIER SCHEMATICS

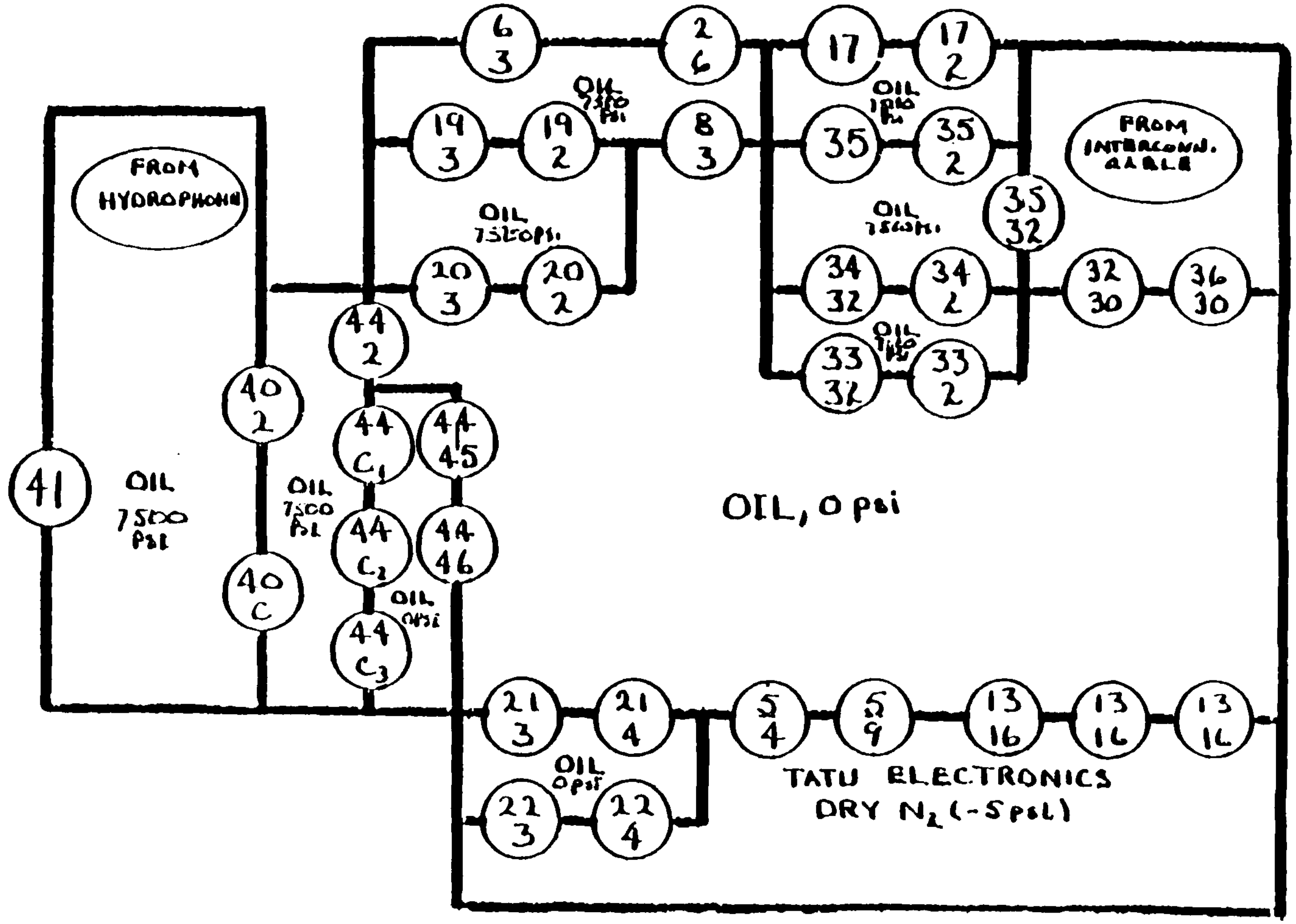
# 10-Connector and Cables



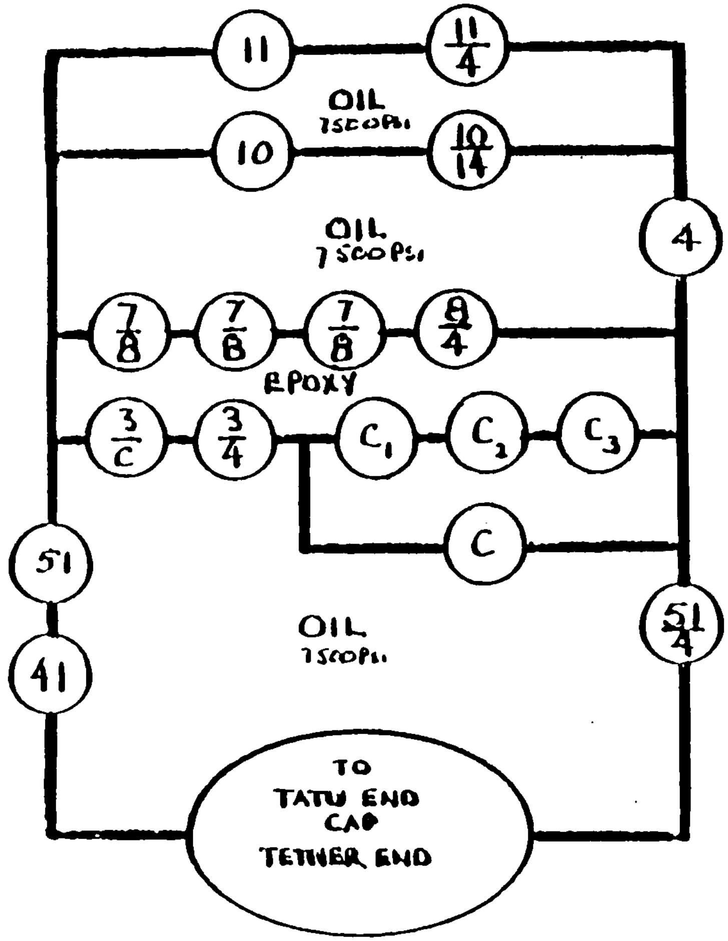
20- TATU ENDCAP



30-TATU END CAP, TETHER END



## 40 - HYDROPHONE AND TETHER CABLE




NOTE: NUMBERS REFER TO ITEMS IN APPROPRIATE SKETCH.

APPENDIX G

MINUTES OF BSURE REPLACEMENT PRELIMINARY DESIGN REVIEW MEETING

5 NOV 1981

UNCLASSIFIED

JAN 15 1982

AIR-6303D/JGC
630-SL-007 AV 222-9182

To: Distribution

Subj: Minutes of BSURE Replacement Preliminary Design Review Mtg; distribution of

Ref: (a) NAVAIR spdltr AIR-6303D/JGC 630-SL-027 of 5 Nov 81, Subj: BSURE TATU Design Analysis

Encl: (1) Minutes of BSURE Replacement Preliminary Design Review Mtg of 17/18 Nov 81

1. Enclosure (1) is provided to document BSURE Design Review mtg of reference (a).

[illegible] Dunbar
By direction

Distribution:
CHESNAVFACENGCOM Washington, DC
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MINUTES OF BSURE REPLACEMENT PRELIMINARY DESIGN REVIEW MEETING

1. This meeting was held 17-18 November 1981 at NAVAIR Headquarters. Attachments (1) and (2) are the revised agenda and list of attendees, respectively. Status of preliminary design analysis of Terminal and Transmission Units (TATUs), sea/shore interface, contract status, and hydrophone spacing were presented by CHESNAVFACENGCOM (CHESDIV), NUSC, and PACMISTESTCEN (PMTC). Design, analysis is continuing and will be presented at the next design review meeting on 13-14 January 1982.

2. LCDR M. Praskievicz (CHESDIV) presented the status of the sea/shore interface investigation. BARSTUR hydrophone, BARSTUR UQC, BSURE hydrophone, and BSURE UCS cables are in jeopardy of failing because of surf damage. CHESDIV will submit a formal report and a proposal recommending a FY-82 short-term repair and a long-term repair after further investigation of courses of action.

3. Mr. R. Cox (CHESDIV), as the design analysis team leader, described the objectives of the analysis. The presentations that followed reported the status of the analysis.

4. Mr. R. Polley (PMTC) presented a history of the TATU design. Vugraphs and some actual components were displayed while the evolution of the design from initial design to the latest redesign was described.

5. Mr. R. Ricci (NUSC) reported on the documentation search conducted at PMTC in early November. There was insufficient time to find, review, and copy all the documentation desired by CHESDIV and NUSC. Concern was expressed about the currentness and completeness of the drawings. An additional concern was that documentation reflects that quality assurance would be completed by Delco with little Government involvement.

6. CHESDIV and NUSC representatives discussed the results of the review of drawings and specifications. CHESDIV did a worse-case tolerance analysis and found that tolerance build-up could prohibit assembly in one case. All O-rings would be compressed 25 to 50% (industry standards are 17 to 24% compression) but no problems are foreseen. No other obvious deficiencies were found. Of some concern to the investigators was a lack of access to the TATU basic design philosophy. Unfortunately the investigators do not have access to the chief designer of the TATU.

7. CHESDIV and NUSC presented results of independent reliability analyses and a review of the preliminary FMEA. Both activities identified lack of empirical reliability data for static seals. Both activities derived equations for the new and old TATU designs and, given hypothetical failure probabilities, arrived at similar results. Their results show, if one assumes each seal has a probability of failure of .10 and all seals have the same probability of failure, the reliability of the new design is greater than 100 times better than the old design. Past failures have been caused by unanticipated problems during assembly of the TATUs. These known problems have been eliminated in the new design but a QA program and environmental testing are required to reduce the chance of other assembly problems causing a failure.



Enclosure (1)

8. Mr. Mike Ho (PMTC) reported on studies done to establish a four-mile hydrophone spacing on each [illegible] replacement string. [illegible] representatives feel the new spacing will provide a tracking area of 1,000 SNM with 18 hydrophones. Scenarios were shown where tracking would not be compromised between the strings by loss of any one hydrophone. A documented investigation will be accomplished when a definite replacement program is identified.

9. Mr. G. Nussear (PMTC) reported on the status of the refurbishment contract with Delco. A list of configuration of deliverables were described.

10. The status of the design analysis objectives were discussed by all participants. The following is a summary of the objectives and comments:

A. Determine whether the new ~~Schedule D~~ SD termination design is worthy of manufacture.

A-1 The Analysis Team agrees that the design approach is fundamentally sound.

A-2 The Analysis Team showed the new design is capable of a significantly higher reliability than the old design and the team will develop tests to verify reliability.

A-3 The Analysis Team did not receive the latest drawings. When the latest drawings are received the team willdetermine whether inherent capability of the new design has been achieved through adequate design particulars as expressed in drawings and specifications. Tolerance analysis needs to be done.

A-4 The Analysis Team agrees that the design is well within state-of-the-art manufacturing techniques and practices.

A-5 The Analysis Team will determine whether design is conducive to acceptance of individual parts through parts inspections when the latest drawings are received.

A-6 The Analysis Team has not seen assembly procedures to determine whether the design is conducive to evaluation test at various levels of assembly.

A-7 The Analysis Team determined that some development tests have been conducted but an integrated test plan is needed.

A-8 Whether the design is overly sensitive to the skill level/motivation of the assembly personnel has yet to be determined.

A-9 The Analysis Team will investigate, including checking with NOS Indian Head, whether the design is conducive to accelerated life tests.

B. Determine whether Delco should be the Manufacturing contractor.

B-1 The Analysis Team has no reservations about Delco.

B-2 It is presently unknown what the impact is if Delco does not provide follow-on support after this manufacturing effort.

C. Determine what additional measures should be taken to assure program success.

C-1 The Analysis Team will continue to provide technical support throughout the program.

C-2 Special quality assurance plans/procedures should be developed/ implemented.

C-3 An integrated test plan should be developed/implemented.

C-4 A Level III drawing package is not required from Delco. The next contractor will formalize drawings if required.

C-5 A quality control and test organization/contractor is required for program success and continuity.

C-6 The Government should participate in, or be involved with, the Delco configuration management plan as much as possible within contract allowance.

11. The following action items were assigned:

a. PMTC to deliver final build-to-print drawings to CHESDIV and NUSC by 1 December 1981.

b. PMTC to obtain assembly procedures and tolerance analyses from Delco Electronics.

c. CHESDIV to coordinate production analysis.

d. NUSC to investigate NOS Indian Head capability to define and conduct accelerated life tests on underwater systems.

12. A critical design review meeting will be held at NAVAIRSYSCOM on 13 and 14 January 1982. Subjects to be discussed are:

a. Status of existing Delco contract.

b. Statement of Work for renegotiated Delco contract.

c. Final report TATU FM&EA

d. Status of design analysis, tolerance analysis, quality assurance plan, integrated test plan, and accelerated life test technique search.

# AGENDA

PRELIMINARY DESIGN REVIEW OF SD TERMINATION (11/17/81)

INTRODUCTION (NAVAIR)

SEA/SHORE INTERFACE STATUS (CHESDIV)

DESIGN ANALYSIS OBJECTIVES (CHESDIV)

SD TERMINATION DESIGN HISTORY (PMTC)

DESIGN DESCRIPTION AND THEORY OF OPERATION OF NEW SD TERMINATION AIDED BY ACTUAL TERMINATION COMPONENT (PMTC)

RESULTS OF OCT 20-23 DOCUMENTATION REVIEW (NUSC)

CURRENT RESULTS OF DRAWING/SPECIFICATION REVIEW (CHESDIV/NUSC)

RESULTS OF FOLLOW-ON FMEA (NUSC)

CURRENT RESULTS OF RELIABILITY ANALYSES (NUSC/CHESDIV)

RESULTS OF HYDROPHONE SPACING INVESTIGATION (PMTC)

STATUS OF REFURBISHMENT CONTRACT (PMTC)

STATUS OF DESIGN ANALYSIS OBJECTIVES (CHESDIV/PMTC/NUSC)

FUTURE PLANS (CHESDIV)

OPEN DISCUSSION AND DETERMINATION OF ACTION ITEMS

BUSURE DESIGN REVIEW MEETING
17 November 1981

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APPENDIX H

RELIABILITY ANALYSIS AND INTEGRATED

TEST PROGRAM FOR THE BSURE TERMINATION

Prepared for

Naval Underwater Systems Center

Newport, RI

Under Contract

N00140-81-D-BB34

Columbia Research Corporation

Arlington, VA

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## 1. INTRODUCTION

Under Contract Number N00140-81-D-BB34 Columbia Research Corporation (CRC) conducted a reliability analysis of the newly designed termination unit used in the Barking Sands Underwater Range Expansion (BSURE) refurbishment program. In addition, CRC developed a test program designed to provide assurance that the termination unit will be capable of functioning, maintenance free, for a period of twenty years. CRC's effort focused on the fluid seals of the termination unit (Morrison seals and O-Rings in a series-parallel configuration). As part of the reliability analysis CRC developed a mathematical model that predicts the performance of the termination unit sealing system as a function of component reliability. The test program is designed primarily to demonstrate the reliability of the termination unit sealing system over the designed service life of the BSURE system.

This report is divided into five sections. Section 1 is the Introduction. Section 2 is the Design Description and contains background information on the BSURE system and a description of the original and the new termination unit design. Section 3 contains the Reliability Analysis; Section 4 provides a series of recommended tests for the New Design; and Section 5 contains Conclusions and Recommendations.

## 2. DESIGN DESCRIPTION

The purpose of the BSURE refurbishment program is to replace the existing BSURE in-water system with an improved system designed to function maintenance-free for a period of twenty years. An important aspect of the replacement system is a newly designed termination unit that provides significantly improved sealing capabilities. As originally designed, the termination unit does not provide adequate protection against seawater entering through the cable core or sheath when the insulation jacket is cut. The new design developed and tested by Delco Electronics, Santa Barbara has been shown to protect against these conditions in laboratory simulation tests. Figures 2-1 and 2-2 are cross-sectional views of the original and new termination unit designs, respectively. The new design has three features which constitute a significant improvement over the original design. These features are: concentric electrical feed-throughs, redundant seals, and pressurized oil cavities.

In the original design, the copper ground sheath is attached to an off-center pin connected to the termination housing bulkhead through a Morrison seal. A leak path developed through this Morrison seal as a result of torque that is normally experienced by the unit. This torque caused relative rotation between the two termination unit sections which in turn caused the pin to move back and forth inside the Morrison seal. The Morrison seal then developed a leak along its interface with the pin causing failure of the termination unit. In the new design, the eccentric pin is eliminated by removing the outer insulating jacket of the SD cable where it enters the termination unit. The copper ground sheath is then folded back and clamped to assure reliable grounding of the termination housing without penetration of the Morrison seal.

The new design is intrinsically more reliable than the original design because it incorporates redundancy to obtain improved sealing characteristics. In the original design, failure of a single seal can result in failure of the termination unit. In the new design, it would take a failure of at least three seals to cause failure of the termination unit.

In both the original and new designs, the termination unit interconnect housing is filled with castor oil. The new design, however, provides a mechanism for the oil cavities to be pressurized to the ambient pressure thus reducing the pressure differential across all seals to zero. The oil-filled termination is pressure-balanced by means of a piston and cylinder mechanism incorporated into the design. An air cavity exists within the cable core, the differential pressure between the ocean and this cavity (which is at atmospheric pressure) tends to drive oil into the cable intersticies. A Morrison seal and a cap seal prevent oil from leaking into the cable.

Figures 2-3 and 2-4 show the termination unit assembly components, and Table 2-1 identifies these components by number, name, material, and function. In Figure 2-4 the termination unit is color-coded to identify various features of the design. Shades of red, blue and grey correspond, respectively, with the paths of high voltage, ground and isolation.

As shown in Figure 2-3, the termination unit consists of two mating assemblies: an SD cable termination assembly and a gimbal assembly. In this figure, the SD cable enters the termination housing from the left. The outer

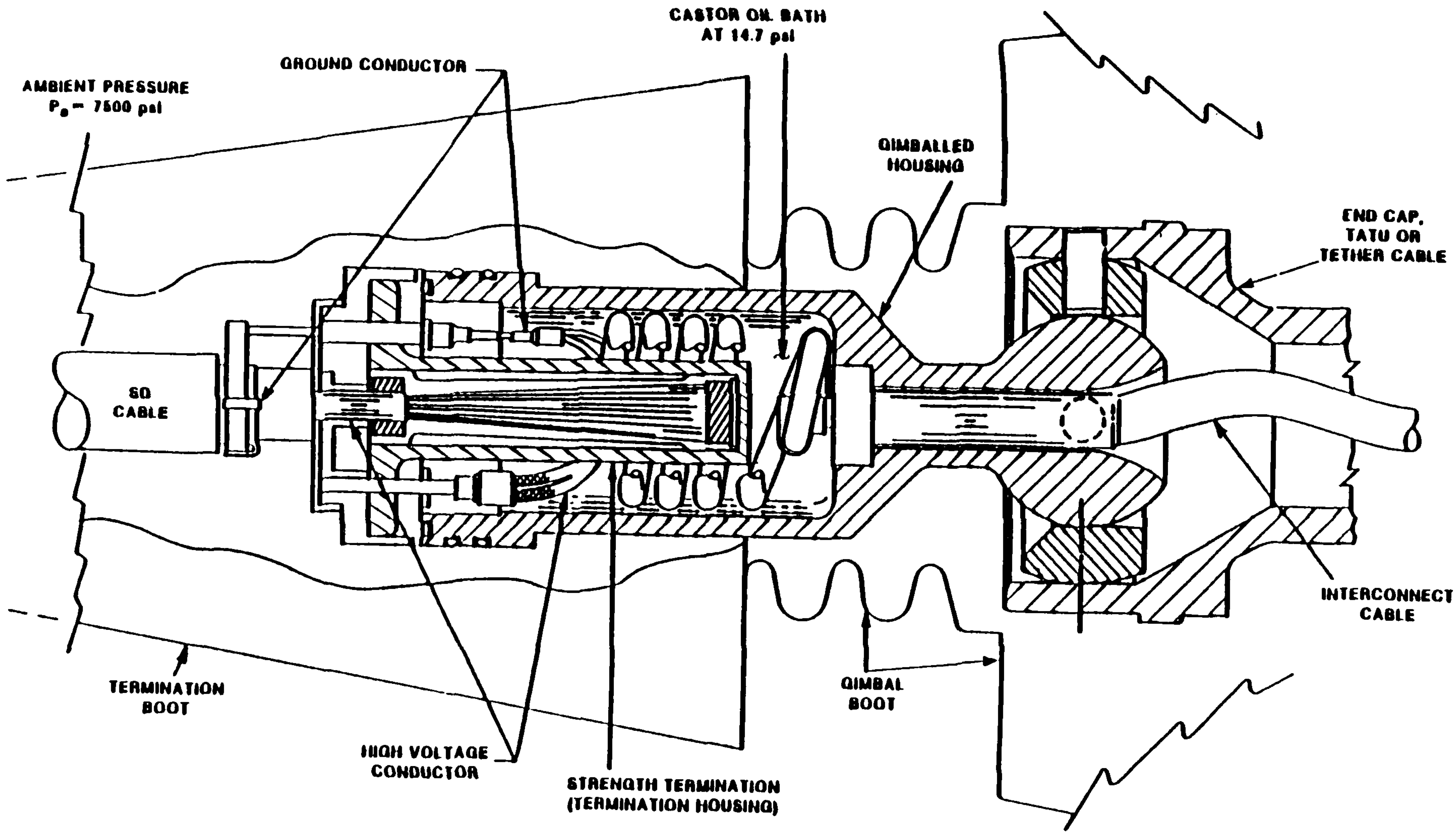



Figure 2-1. Original Design Termination Unit Cross Section

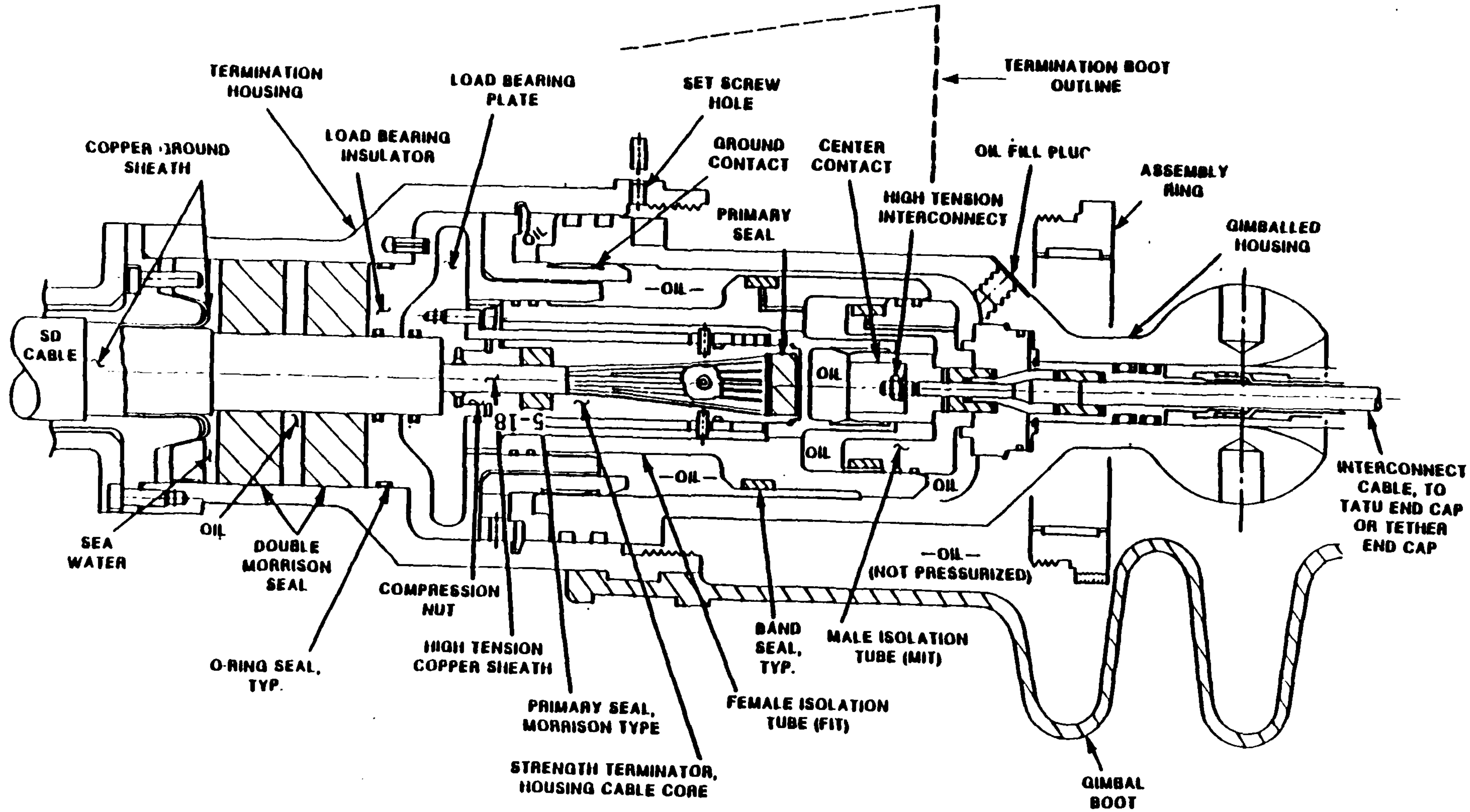



Figure 2-2. New Design Termination Unit Cross Section

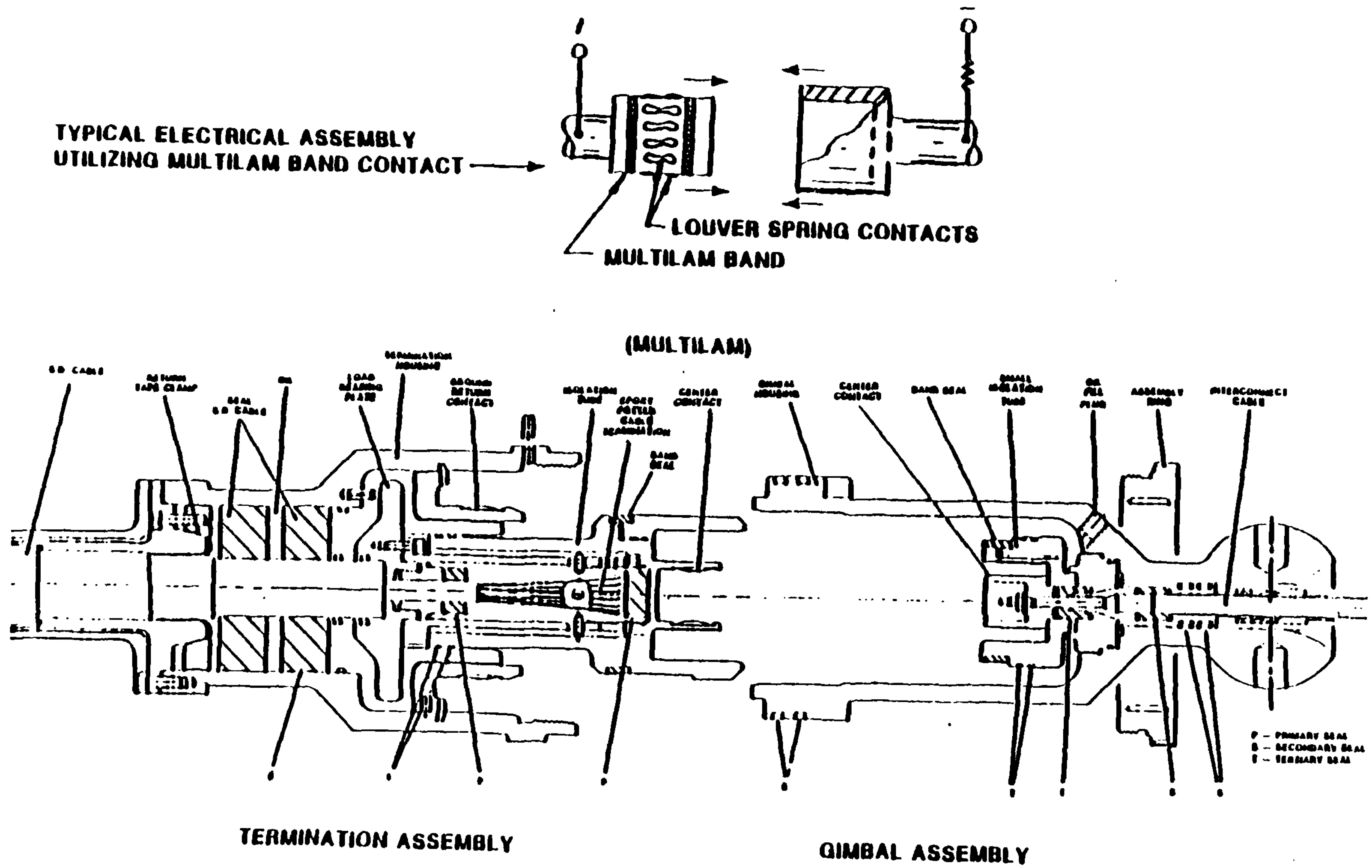



Figure 2-3. Termination Unit Showing Unmated SD Cable Termination and Gimbal Assemblies

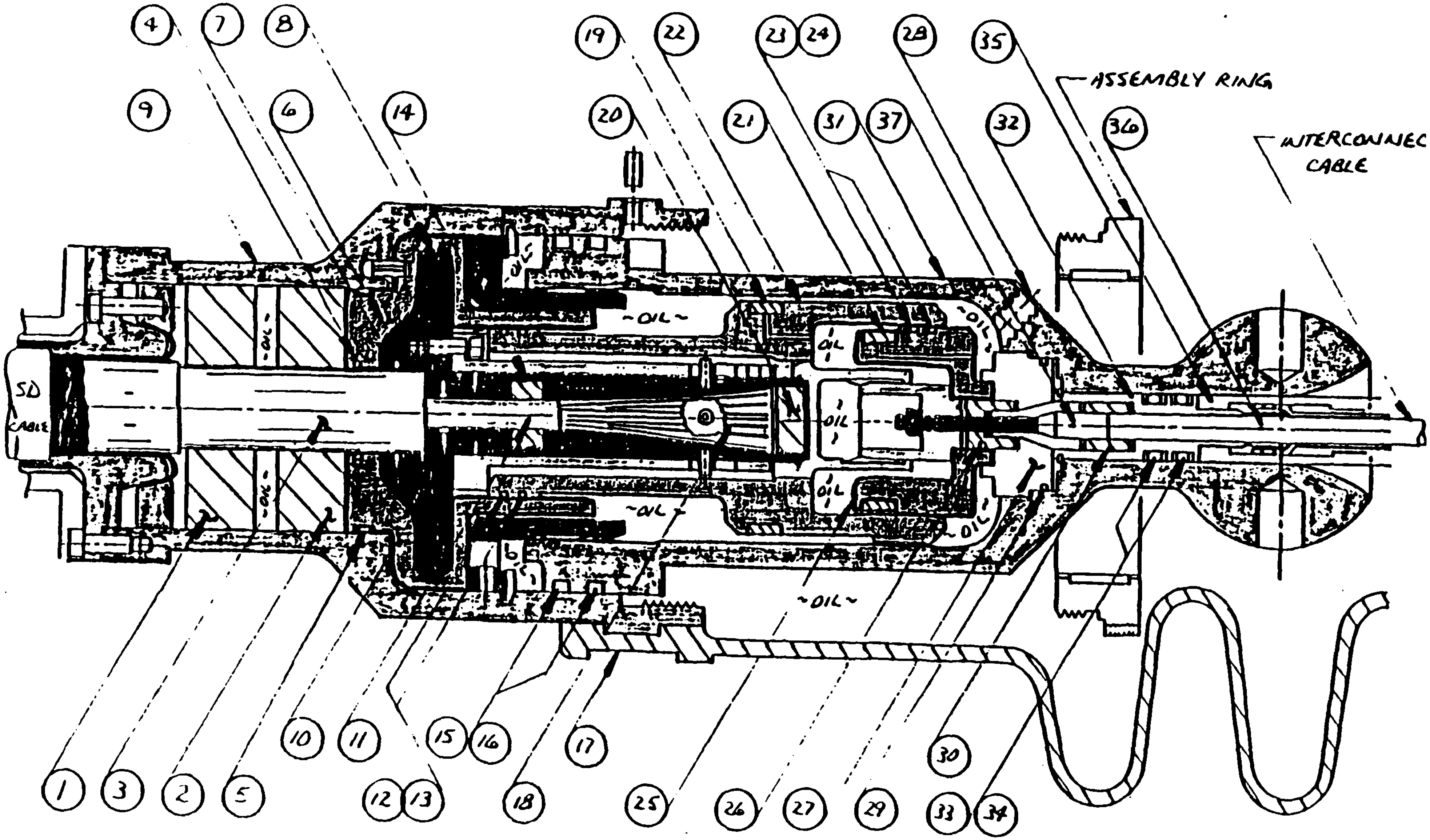



Fig. 2-4: TATU termination unit, showing parts and color coded conduction path (red - high voltage, blue - ground, grey - insulation). Parts itemized and identified according to Table 2-1.

TABLE 2-1
TERMINATION UNIT COMPONENTS

| FIG. 2-4 IDENT. NUMBER | NOMENCLATURE | MATERIAL | FUNCTION |
|---|---|---|---|
| 1 | Morrison Seal, Cable Sheath | Silicon Elastomer | Secondary sealing, termination housing-to-polyethelyne sheath |
| 2 | Morrison Seal, Cable Sheath | Butyl | Secondary sealing, termination housing-to-polyethelyne sheath |
| 3 | SD Center Insulation | Polyethelyne | Multiplex signal carrier |
| 4 | O-Ring | Butyl | Seal, fiberglass-to-polyethelyne sheath |
| 5 | O-Ring | Butyl | Seal, housing-to-fiberglass |
| 6 | Load Bearing Insulator | Epoxy-Fiberglass | Encases and isolates load bearing plate from ground |
| 7 | O-Ring | Butyl | Seal, load bearing plate-to-polyethelyne sheath |
| 8 | Load Bearing Plate | Steel | Assumes axial loads applied to TATU |
| 9 | Termination Housing | Copper Nickel Beryllium | Encasement and ground conductor |
| 10 | Compression Fitting | Copper | Secures high-tension copper conductor to load bearing plate |
| 11 | High-Tension Cable Conductor | Copper | Multiplex Signal Carrier |
| 12 | O-Ring | Butyl | Tertiary seal, load bearing insulator-to-tertiary Female Insulator Tube (FIT) |
| 13 | O-Ring | Butyl | Seal, load bearing insulator-to-FIT |
| 14 | Morrison Seal | Butyl | Primary seal, blocks oil passage into cable core |

TABLE 2-1
TERMINATION UNIT COMPONENTS (Contd)

| FIG. 2-4 IDENT. NUMBER | NOMENCLATURE | MATERIAL | FUNCTION |
|---|---|---|---|
| 15 | O-Ring | Butyl | Secondary seal, termination housing to gimbal housing |
| 16 | O-Ring | Butyl | Secondary seal, termination housing to gimbal housing |
| 17 | Gimbal Boot | Butyl | Flexible rubber bellows covering gimbal joint |
| 18 | Strength Terminator | Steel & Epoxy | Potted cable core termination |
| 19 | Female Isolation Tube (FIT) Band Seal | Silicone Elastomer | Fluid pressure equalizer and conductive path seal between oil cavities |
| 20 | Morrison Seal | Butyl | Primary seal |
| 21 | Male Isolation Tube (MIT) Band Seal | Silicone Elastomer | Fluid pressure equalizer and conductive path seal between oil cavities |
| 22 | Female Isolation Tube (FIT) | PVC | Termination housing center contact isolator |
| 23 | Male Isolation Tube (MIT) O-Ring | Butyl | Tertiary seal, MIT-to-FIT |
| 24 | MIT O-Ring | Butyl | Tertiary seal, MIT-to-FIT |
| 25 | Male Isolation Tube (MIT) | PVC | Gimbal housing center contact isolator |
| 26 | Interconnect Termination Seal | Butyl | Tertiary seal, MIT-to-interconnect cable |
| 27 | Taper Unit | Copper Nickel Beryllium | To retain interconnect cable termination |
| 28 | Oil-Fill Plug | Copper Nickle | Oil-fill and pressurization |
| 29 | O-Ring | Butyl | Seal |

TABLE 2-1
TERMINATION UNIT COMPONENTS (Contd)

| FIG. 2-4 IDENT. NUMBER | NOMENCLATURE | MATERIAL | FUNCTION |
|---|---|---|---|
| 30 | Core Seal | Butyl | Secondary seal, cable spool-to-interconnect cable |
| 31 | Gimballed Housing | Copper Nickel Beryllium | Flexible joint-to-end cap assembly |
| 32 | Cable Spool | 7030 Copper | Interfaces the cable boot and the interconnect cable terminal |
| 33 | O-Ring | Butyl | Secondary seal, cable spool-to-gimbal neck |
| 34 | O-Ring | Butyl | Secondary seal, cable spool-to-gimbal neck |
| 35 | Interconnect Cable Boot | Butyl | Provides secondary seal between the cable spool and the gimbal |
| 36 | Interconnect Cable Core | Copper | Connects interconnect cable core to the termination unit |
| 37 | Interconnect Cable Terminal | Copper | Terminates conductor |

sheath is removed and the copper ground sheath is folded back and clamped. Seawater is in contact with the cable sheath at this point. An underlying polyethelyne dialectric protecting the signal carrier is passed through a pair of Morrison seals separated by castor oil. The polyethelyne dialectric is then passed through the load bearing insulator and terminates within the load bearing plate. At the termination of the polyethelyne dialectric the high-voltage copper sheath is exposed and secured to the load bearing plate via a copper compression fitting. An electrical conduction path is established through this fitting, through the steel load bearing plate and then through the strength terminator encasement to the center contact. This contact is achieved through use of a Multilam Band (see accompanying detail in Figure 2-3), designed and patented by Brown Boveri Co. of Switzerland. The Multilam Band is a flat band formed into a cylindrcal shape from heat-treated and gold-plated beryllium copper. The material is processed to provide multiple louver-shaped spring contacts at the mating interface. Thus, a highly reliable elastic connection is formed with multiple-line contacts operating at thousands of pounds per square inch.

The termination unit provides a mechanical connection between the SD cable and the TATU housing. Axial strength is required during deployment operations to support the cable in 15,000 feet of water.

When the two assemblies are mated, an electrical path is completed through the gimibal center contact and out through the core of the gimbal interconnect cable into the TATU housing. The assembly ring secures the two termination unit assemblies and permits relative linear motion to achieve pressure equalization. The male and female isolation tubes (MITs and FITs) are designed with band seals which permit pressure equalization between the two oil cavities while preventing an electrical path to be completed between high voltage and ground. The outer gimbal boot is also oil-filled.

## 3. RELIABILITY ANALYSIS

CRC conducted a reliability analysis of the termination unit. In this analysis reliability equations for the new and original termination unit designs were developed from system block diagrams and success state tables. The equations were solved for hypothetical reliability values of Morrison seals and O-rings. A comparison of the reliability performance characteristics of the new and original designs was then made. This comparative analysis confirmed the superior reliability performance of the new design. The details of the reliability analysis are presented in this section of the report.

### 3.1 Assumptions

Due to the lack of applicable reliability data for elastomeric seals, the following simplifying assumptions are used to govern the approach of the reliability analysis:

(1) Constant Failure Rate For Morrison Seals and O-Rings. The first assumption made for this analysis is that Morrison seals and O-rings have a constant failure rate. This assumption is frequently employed in reliability analyses and very little error is caused by its use. This assumption simplifies the mathematics and allows the use of the equation:

$$R = e^{-\lambda t}$$

where R = probability of survival, (dimensionless)
$\lambda$ = the constant failure rate, ($hrs^{-1}$)
t = time (hrs)
e = 2.71828, (dimensionless)

(2) Identical Failure Rate For All Seals. The second assumption is that all seals, Morrison seals and O-rings, have identical failure rates. This assumption was made because actual failure rate data for these components could not be located. Since there are similarities in the design, elastomeric composition, application, and environment of both Morrison seals and O-rings, and since both the new and original design employ both types of seals, it appears that this assumption is valid for a comparative analysis.

(3) Negligible Effects Due To The Oil. In this analysis the effects of castor oil on the failure rate of the seals have been neglected. It is generally believed that the use of oil in the new design will have beneficial effects on the reliability of the termination unit. In the new design the oil is pressurized to ambient causing a zero pressure differential across the seals. The reliability analysis neglects this effect. It is therefore felt that the actual reliability performance of the new design might be better than predicted.

### 3.2 Comparative Reliability Analysis

At the beginning of the reliability analysis, failure rate data on O-Rings and Morrison seals was not available and therefore an accurate prediction of termination unit reliability could not be made. In the absence of this data, it was decided to conduct a comparative analysis between the original termination unit design and the new design.

The first step in conducting the comparative reliability analysis was to develop a block diagram. The block diagrams for the original design and the new design had been prepared by CHESNAVFACENGCOM and PMTC. Figure 3-1 shows the block diagrams for the original design. Using this block diagram, all the possible success states of the termination unit were listed. A success state is any condition in which the termination unit will function as required even though one or more components have failed. All combinations of failed and functioning components that result in system success comprise the system success states. These success states are shown in Table 3-1. The letter "A" in the table indicates that the Morrison seal at position A in the block diagram is functioning properly. The "$\underline{A}$" in the table indicates that the Morrison seal at position A in the block diagram has failed.

The reliability equation for the unit can be written directly from the table of success states. This is accomplished by writing a probability term for each success state. For instance, the success state A B C D E yields the term $X^5$. Similarly the success state A $\underline{B}$ F G C D E yields the term $X^6 (1-X)$. Adding all these terms gives the equation shown in Table 3-2. Substituting various values for X and solving for $R_{od}$ (reliability of original design) gives the values shown in Table 3-2. These values were then plotted as shown in Figure 3-2.

The same process was accomplished for the new design. Figure 3-3 shows the block diagram for the new design, Table 3-3 shows the success states for the new design, Table 3-4 shows the reliability equation derived from the success states, and Table 3-5 shows the simplified reliability equation for the new design and the reliability values. Figure 3-4 shows the comparison of original unit reliability to new unit reliability. From this figure it can be seen that the new design is considerably more reliable than the original.

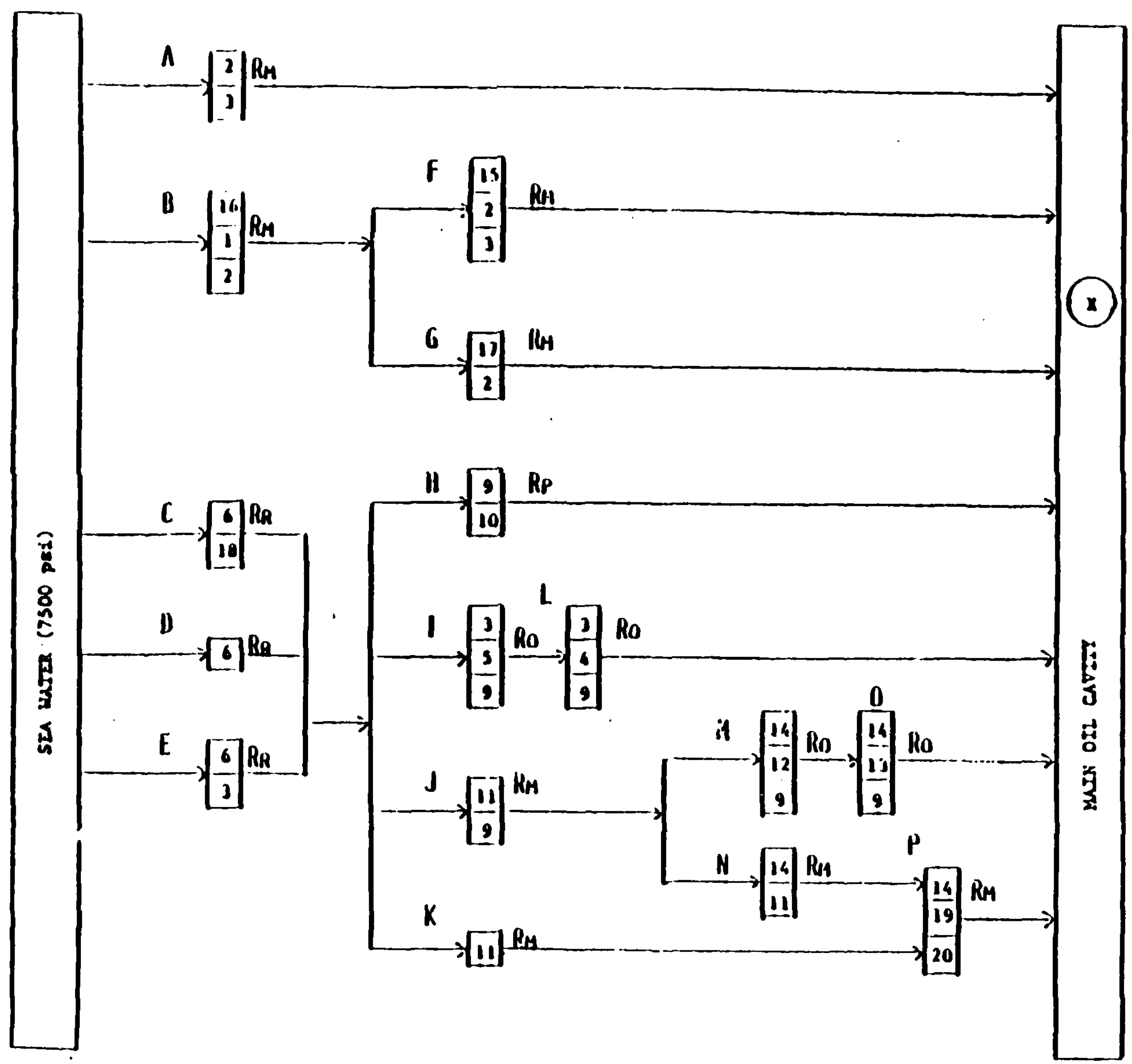



Figure 3-1. Block Diagram of the Original Termination Unit Design

TABLE 3-1

SUCCESS STATES FOR THE ORIGINAL TERMINATION UNIT DESIGN

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1- | A | B | C | D | E | | | | | | | | | |
| 2- | A | $\underline{B}$ | F | G | C | D | E | | | | | | | |
| 3- | A | B | $\underline{C}$ | H | I | J | K | | | | | | | |
| 4- | A | $\underline{B}$ | F | G | $\underline{C}$ | H | I | J | K | | | | | |
| 5- | A | B | $\underline{C}$ | H | $\underline{I}$ | L | J | K | | | | | | |
| 6- | A | $\underline{B}$ | F | G | $\underline{C}$ | H | $\underline{I}$ | L | J | K | | | | |
| 7- | A | B | $\underline{C}$ | H | I | $\underline{J}$ | M | N | K | | | | | |
| 8- | A | $\underline{B}$ | F | G | $\underline{C}$ | H | I | $\underline{J}$ | M | N | K | | | |
| 9- | A | B | $\underline{C}$ | H | $\underline{I}$ | L | $\underline{J}$ | M | N | K | | | | |
| 10- | A | $\underline{B}$ | F | G | $\underline{C}$ | H | $\underline{I}$ | L | $\underline{J}$ | M | N | K | | |
| 11- | A | B | $\underline{C}$ | H | I | $\underline{J}$ | $\underline{M}$ | O | N | K | | | | |
| 12- | A | $\underline{B}$ | F | G | C | H | I | $\underline{J}$ | $\underline{M}$ | O | N | K | | |
| 13- | A | B | $\underline{C}$ | H | $\underline{I}$ | L | $\underline{J}$ | $\underline{M}$ | O | N | K | | | |
| 14- | A | $\underline{B}$ | F | G | $\underline{C}$ | H | $\underline{I}$ | L | $\underline{J}$ | $\underline{M}$ | O | N | K | |
| 15- | A | B | $\underline{C}$ | H | I | $\underline{J}$ | $\underline{M}$ | O | $\underline{N}$ | P | | | | |
| 16- | A | $\underline{B}$ | F | G | $\underline{C}$ | H | I | $\underline{J}$ | $\underline{M}$ | O | $\underline{N}$ | P | | |
| 17- | A | B | $\underline{C}$ | H | $\underline{I}$ | L | $\underline{J}$ | $\underline{M}$ | O | $\underline{N}$ | P | | | |
| 18- | A | $\underline{B}$ | F | G | $\underline{C}$ | H | $\underline{I}$ | L | $\underline{J}$ | $\underline{M}$ | O | $\underline{N}$ | P | |
| 19- | A | B | $\underline{C}$ | H | I | J | $\underline{K}$ | P | | | | | | |
| 20- | A | $\underline{B}$ | F | G | $\underline{C}$ | H | I | J | $\underline{K}$ | P | | | | |
| 21- | A | B | $\underline{C}$ | H | $\underline{I}$ | L | J | $\underline{K}$ | P | | | | | |
| 22- | A | $\underline{B}$ | F | G | $\underline{C}$ | H | $\underline{I}$ | L | J | $\underline{K}$ | P | | | |
| 23- | A | B | $\underline{C}$ | H | $\underline{I}$ | L | $\underline{J}$ | M | N | $\underline{K}$ | P | | | |
| 24- | A | $\underline{B}$ | F | G | $\underline{C}$ | H | $\underline{I}$ | L | $\underline{J}$ | M | N | $\underline{K}$ | P | |
| 25- | A | B | $\underline{C}$ | H | $\underline{I}$ | L | $\underline{J}$ | $\underline{M}$ | O | N | $\underline{K}$ | P | | |
| 26- | A | $\underline{B}$ | F | G | $\underline{C}$ | H | $\underline{I}$ | L | $\underline{J}$ | $\underline{M}$ | O | N | $\underline{K}$ | P |
| 27- | A | B | $\underline{C}$ | H | I | $\underline{J}$ | M | N | $\underline{K}$ | P | | | | |
| 28- | A | $\underline{B}$ | F | G | $\underline{C}$ | H | I | $\underline{J}$ | M | N | $\underline{K}$ | P | | |

29-54-Same as states 3 through 28 but replace C with D.

55-80-Same as states 3 through 28 but replace C with E.

TABLE 3-2
RELIABILITY OF THE ORIGINAL DESIGN VERSUS SEAL RELIABILITY

| $X = R_s$ | $R_{od}$ |
|---|---|
| .0 | .0 |
| .4 | .0048 |
| .5 | .137 |
| .6 | .292 |
| .7 | .500 |
| .8 | .718 |
| .82 | .757 |
| .84 | .794 |
| .86 | .828 |
| .88 | .860 |
| .90 | .889 |
| .92 | .917 |
| .94 | .938 |
| .96 | .96 |
| .98 | .98 |
| .999 | .999 |
| 1.0 | 1.0 |

$$
\begin{aligned}
R_{od} = \; & X^5 + 4X^6(1-X) + 6X^6(1-X)^2 + 3X^6(1-X)^3 \\
& + 3X^6(1-X)^4 + 3X^6(1-X)^5 + 9X^7(1-X)^2 + 12X^7(1-X)^3 \\
& + 9X^7(1-X)^4 + 6X^7(1-X)^5 + 3X^7(1-X)^6 + 6X^8(1-X)^3 \\
& + 6X^8(1-X)^4 + 6X^8(1-X)^5 + 3X^8(1-X)^6
\end{aligned}
$$

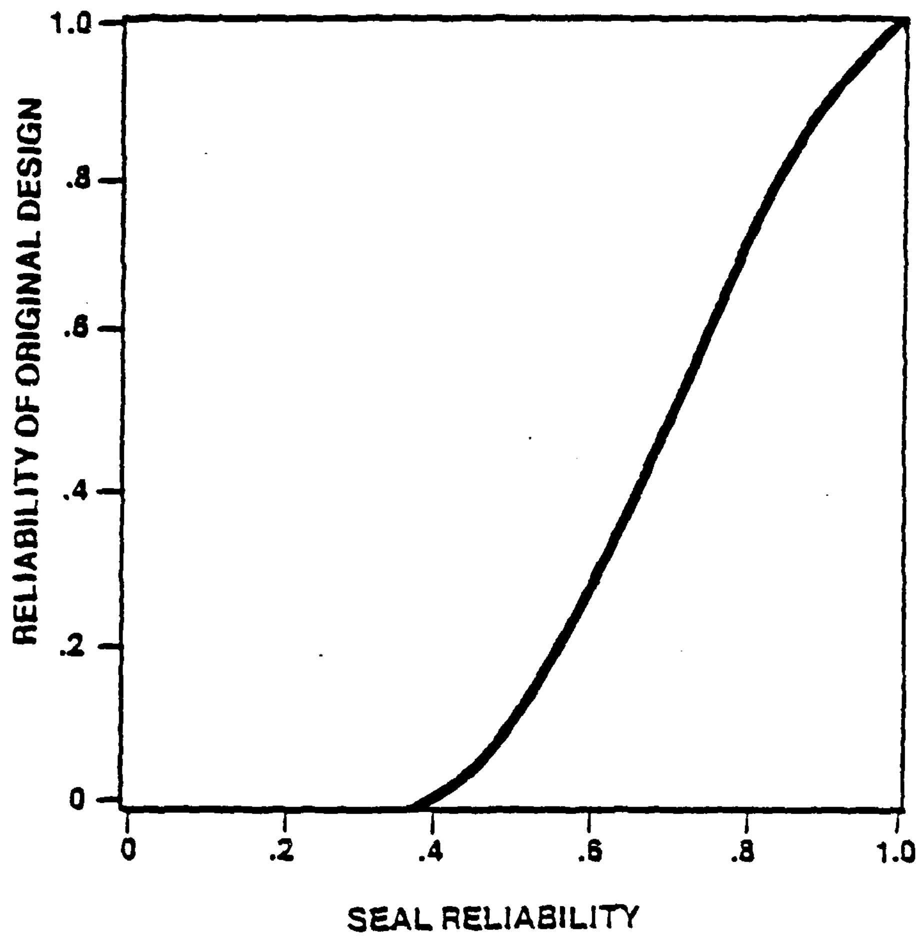



Figure 3-2. Reliability of Original Design ($R_{od}$) Versus Seal Reliability (Rs)

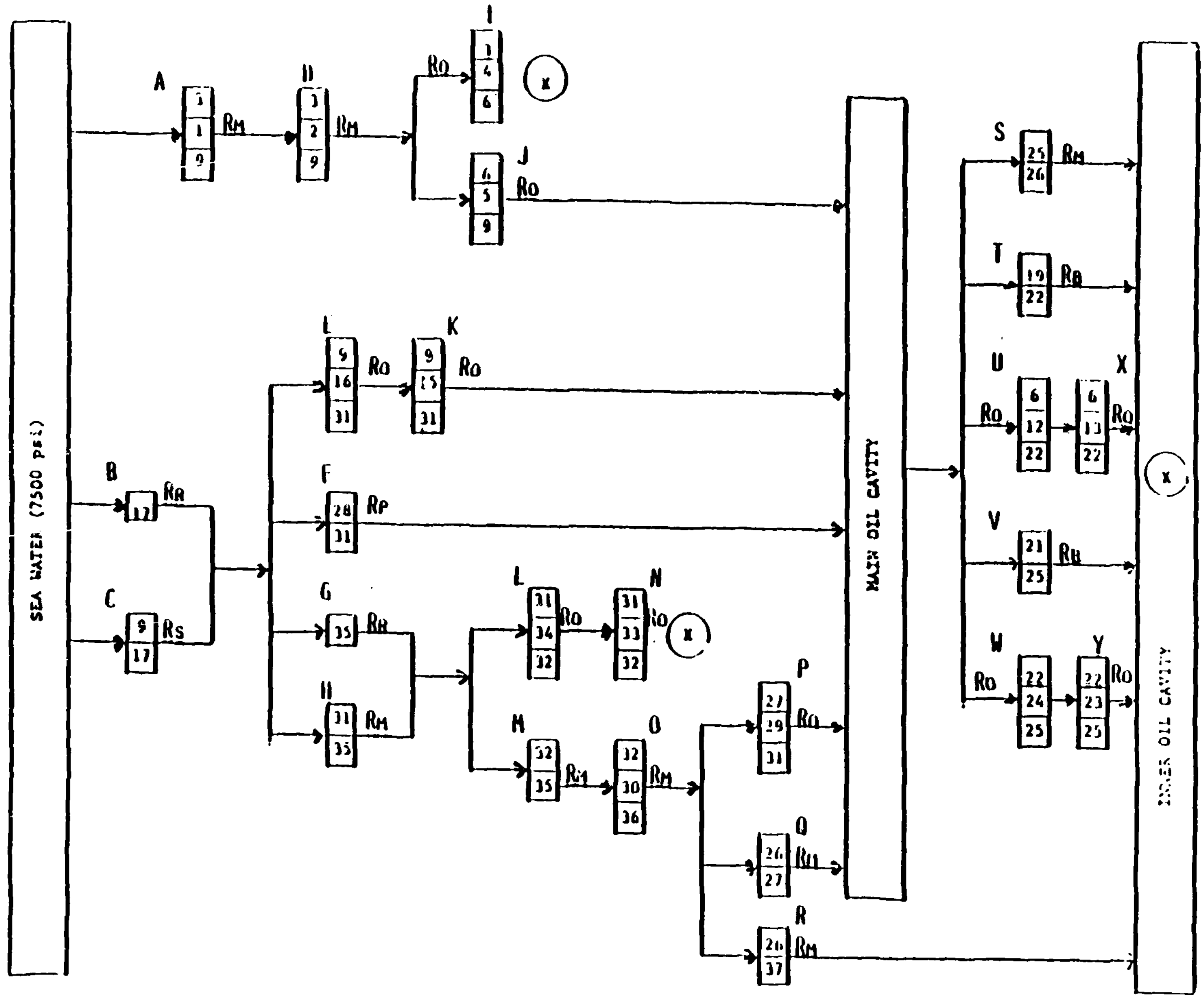



Figure 3-3. Block Diagram for the New Termination Unit Design

TABLE 3-3
SYSTEM SUCCESS STATES FOR THE NEW DESIGN

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1- | A | $\underline{B}$ | C | | | | | | | | | | | | | | |
| 2- | A | $\underline{B}$ | $\underline{E}$ | F | G | H | | | | | | | | | | | |
| 3- | A | $\underline{B}$ | $\underline{E}$ | K | F | G | H | | | | | | | | | | |
| 4- | A | $\underline{B}$ | $\underline{E}$ | F | $\underline{G}$ | L | M | | | | | | | | | | |
| 5- | A | $\underline{B}$ | $\underline{E}$ | K | F | $\underline{G}$ | L | M | | | | | | | | | |
| 6- | A | $\underline{B}$ | $\underline{E}$ | F | $\underline{G}$ | $\underline{L}$ | N | M | | | | | | | | | |
| 7- | A | $\underline{B}$ | $\underline{E}$ | K | F | $\underline{G}$ | $\underline{L}$ | N | M | | | | | | | | |
| 8- | A | $\underline{B}$ | $\underline{E}$ | F | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | O | | | | | | | | |
| 9- | A | $\underline{B}$ | $\underline{E}$ | K | F | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | O | | | | | | | |
| 10- | A | $\underline{B}$ | $\underline{E}$ | F | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | $\underline{O}$ | P | Q | R | | | | | |
| 11- | A | $\underline{B}$ | $\underline{E}$ | K | F | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | $\underline{O}$ | P | Q | R | | | | |
| 12- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | U | V | W | G | H | | | | | | |
| 13- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | $\underline{U}$ | X | V | W | G | H | | | | | |
| 14- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | $\underline{U}$ | X | V | $\underline{W}$ | Y | G | H | | | | |
| 15- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | U | V | $\underline{W}$ | Y | G | H | | | | | |
| 16- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | U | V | W | $\underline{G}$ | L | M | | | | | |
| 17- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | $\underline{U}$ | X | V | W | $\underline{G}$ | L | M | | | | |
| 18- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | $\underline{U}$ | X | V | $\underline{W}$ | Y | $\underline{G}$ | L | M | | | |
| 19- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | U | V | $\underline{W}$ | Y | $\underline{G}$ | L | M | | | | |
| 20- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | U | V | W | $\underline{G}$ | $\underline{L}$ | N | M | | | | |
| 21- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | $\underline{U}$ | X | V | W | $\underline{G}$ | $\underline{L}$ | N | M | | | |
| 22- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | $\underline{U}$ | X | V | $\underline{W}$ | Y | $\underline{G}$ | $\underline{L}$ | N | M | | |
| 23- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | U | V | $\underline{W}$ | Y | $\underline{G}$ | $\underline{L}$ | N | M | | | |
| 24- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | U | V | W | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | O | | | |
| 25- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | $\underline{U}$ | X | V | W | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | O | | |
| 26- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | $\underline{U}$ | X | V | $\underline{W}$ | Y | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | O | |
| 27- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | U | V | $\underline{W}$ | Y | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | O | | |
| 28- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | U | V | W | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | $\underline{O}$ | R | | |
| 29- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | $\underline{U}$ | X | V | W | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | $\underline{O}$ | R | |
| 30- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | $\underline{U}$ | X | V | $\underline{W}$ | Y | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | $\underline{O}$ | R |
| 31- | A | $\underline{B}$ | $\underline{E}$ | $\underline{K}$ | S | T | U | V | $\underline{W}$ | Y | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | $\underline{O}$ | R | |
| 32- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | U | V | W | G | H | | | | | | |
| 33- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | $\underline{U}$ | X | V | W | G | H | | | | | |
| 34- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | $\underline{U}$ | X | V | $\underline{W}$ | Y | G | H | | | | |
| 35- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | U | V | $\underline{W}$ | Y | G | H | | | | | |
| 36- | A | $\underline{B}$ | $\underline{E}$ | K | $\underline{F}$ | S | T | U | V | W | G | H | | | | | |
| 37- | A | $\underline{B}$ | $\underline{E}$ | K | $\underline{F}$ | S | T | $\underline{U}$ | X | V | W | G | H | | | | |
| 38- | A | $\underline{B}$ | $\underline{E}$ | K | $\underline{F}$ | S | T | $\underline{U}$ | X | V | $\underline{W}$ | Y | G | H | | | |
| 39- | A | $\underline{B}$ | $\underline{E}$ | K | $\underline{F}$ | S | T | U | V | $\underline{W}$ | Y | G | H | | | | |
| 40- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | U | V | W | $\underline{G}$ | L | M | | | | | |
| 41- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | $\underline{U}$ | X | V | W | $\underline{G}$ | L | M | | | | |
| 42- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | $\underline{U}$ | X | V | $\underline{W}$ | Y | $\underline{G}$ | L | M | | | |
| 43- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | U | V | $\underline{W}$ | Y | $\underline{G}$ | L | M | | | | |
| 44- | A | $\underline{B}$ | $\underline{E}$ | K | $\underline{F}$ | S | T | U | V | W | $\underline{G}$ | L | M | | | | |
| 45- | A | $\underline{B}$ | $\underline{E}$ | K | $\underline{F}$ | S | T | $\underline{U}$ | X | V | W | $\underline{G}$ | L | M | | | |
| 46- | A | $\underline{B}$ | $\underline{E}$ | K | $\underline{F}$ | S | T | $\underline{U}$ | X | V | $\underline{W}$ | Y | $\underline{G}$ | L | M | | |
| 47- | A | $\underline{B}$ | $\underline{E}$ | K | $\underline{F}$ | S | T | U | V | $\underline{W}$ | Y | $\underline{G}$ | L | M | | | |
| 48- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | U | V | W | $\underline{G}$ | $\underline{L}$ | N | M | | | | |
| 49- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | $\underline{U}$ | X | V | W | $\underline{G}$ | $\underline{L}$ | N | M | | | |
| 50- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | $\underline{U}$ | X | V | $\underline{W}$ | Y | $\underline{G}$ | $\underline{L}$ | N | M | | |
| 51- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | U | V | $\underline{W}$ | Y | $\underline{G}$ | $\underline{L}$ | N | M | | | |
| 52- | A | $\underline{B}$ | $\underline{E}$ | K | $\underline{F}$ | S | T | U | V | W | $\underline{G}$ | $\underline{L}$ | N | M | | | |
| 53- | A | $\underline{B}$ | $\underline{E}$ | K | $\underline{F}$ | S | T | $\underline{U}$ | X | V | W | $\underline{G}$ | $\underline{L}$ | N | M | | |
| 54- | A | $\underline{B}$ | $\underline{E}$ | K | $\underline{F}$ | S | T | $\underline{U}$ | X | V | $\underline{W}$ | Y | $\underline{G}$ | $\underline{L}$ | N | M | |
| 55- | A | $\underline{B}$ | $\underline{E}$ | K | $\underline{F}$ | S | T | U | V | $\underline{W}$ | Y | $\underline{G}$ | $\underline{L}$ | N | M | | |
| 56- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | U | V | W | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | O | | | |
| 57- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | $\underline{U}$ | X | V | W | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | O | | |
| 58- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | $\underline{U}$ | X | V | $\underline{W}$ | Y | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | O | |
| 59- | A | $\underline{B}$ | E | $\underline{F}$ | S | T | U | V | $\underline{W}$ | Y | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | O | | |
| 60- | A | $\underline{B}$ | $\underline{E}$ | K | $\underline{F}$ | S | T | U | V | W | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | O | | |

## TABLE 3-3
## SYSTEM SUCCESS STATES FOR THE NEW DESIGN (Contd)

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 61- | A | B | E | K | F | S | T | U | X | V | W | G | L | N | M | O | | |
| 62- | A | $\bar{B}$ | $\bar{E}$ | K | $\bar{F}$ | S | T | $\bar{U}$ | X | V | W | $\bar{Y}$ | $\bar{G}$ | L | $\bar{N}$ | M | O | |
| 63- | A | $\bar{B}$ | $\bar{E}$ | K | $\bar{F}$ | S | T | $\bar{U}$ | V | W | $\bar{Y}$ | G | $\bar{L}$ | $\bar{N}$ | M | $\bar{O}$ | | |
| 64- | A | $\bar{B}$ | $\bar{E}$ | F | $\bar{S}$ | T | U | $\bar{V}$ | W | $\bar{G}$ | L | $\bar{N}$ | $\bar{M}$ | O | $\bar{R}$ | | | |
| 65- | A | $\bar{B}$ | E | $\bar{F}$ | S | T | U | X | V | $\bar{W}$ | $\bar{G}$ | L | $\bar{N}$ | $\bar{M}$ | O | R | | |
| 66- | A | $\bar{B}$ | E | $\bar{F}$ | S | T | $\bar{U}$ | X | V | W | $\bar{Y}$ | $\bar{G}$ | L | $\bar{N}$ | $\bar{M}$ | O | R | |
| 67- | A | $\bar{B}$ | E | $\bar{F}$ | S | T | $\bar{U}$ | V | W | $\bar{Y}$ | G | $\bar{L}$ | $\bar{N}$ | M | $\bar{O}$ | $\bar{R}$ | | |
| 68- | A | $\bar{B}$ | E | $\bar{K}$ | F | S | T | U | $\bar{V}$ | W | $\bar{G}$ | $\bar{L}$ | N | $\bar{M}$ | $\bar{O}$ | R | | |
| 69- | A | $\bar{B}$ | $\bar{E}$ | K | $\bar{F}$ | S | T | U | X | V | $\bar{W}$ | $\bar{G}$ | L | $\bar{N}$ | $\bar{M}$ | O | R | |
| 70- | A | $\bar{B}$ | $\bar{E}$ | K | $\bar{F}$ | S | T | $\bar{U}$ | X | V | W | $\bar{Y}$ | $\bar{G}$ | L | $\bar{N}$ | $\bar{M}$ | O | R |
| 71- | A | $\underline{\bar{B}}$ | $\underline{\bar{E}}$ | K | $\underline{\bar{F}}$ | S | T | $\bar{U}$ | V | $\underline{W}$ | $\bar{Y}$ | $\underline{G}$ | $\bar{L}$ | $\bar{N}$ | $\underline{M}$ | $\underline{\bar{O}}$ | $\bar{R}$ | |

Steps 72 Thru 142, Repeat Steps 1 Thru 71 Replacing (A) By (AD)
Steps 143 Thru 213, Repeat Steps 1 Thru 71 Replacing (A) By ($\overline{A}$$\underline{D}$IJ)

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 214- | A | O | I | J | S | T | U | V | W | B | C | | | | | | | | |
| 215- | $\bar{A}$ | $\bar{O}$ | I | $\bar{J}$ | S | T | U | X | V | W | B | C | | | | | | | |
| 216- | $\bar{A}$ | $\bar{O}$ | I | $\bar{J}$ | S | T | $\bar{U}$ | X | V | W | Y | B | C | | | | | | |
| 217- | $\bar{A}$ | $\bar{O}$ | I | $\bar{J}$ | S | T | $\bar{U}$ | V | W | $\bar{Y}$ | B | C | | | | | | | |
| 218- | $\bar{A}$ | $\bar{O}$ | I | $\bar{J}$ | S | T | U | V | $\bar{W}$ | B | E | F | G | H | | | | | |
| 219- | $\bar{A}$ | $\bar{O}$ | I | $\bar{J}$ | S | T | U | X | V | $\bar{W}$ | B | E | F | G | H | | | | |
| 220- | $\bar{A}$ | $\bar{O}$ | I | $\bar{J}$ | S | T | $\bar{U}$ | X | V | W | $\bar{Y}$ | B | E | F | G | H | | | |
| 221- | $\bar{A}$ | $\bar{O}$ | I | $\bar{J}$ | S | T | $\bar{U}$ | V | W | $\bar{Y}$ | B | $\bar{E}$ | F | G | H | | | | |
| 222- | $\bar{A}$ | $\bar{O}$ | I | $\bar{J}$ | S | T | U | V | $\bar{W}$ | B | $\bar{E}$ | K | F | G | H | | | | |
| 223- | $\bar{A}$ | $\bar{O}$ | I | $\bar{J}$ | S | T | U | X | V | $\bar{W}$ | $\bar{B}$ | $\bar{E}$ | K | F | G | H | | | |
| 224- | $\bar{A}$ | $\bar{O}$ | I | $\bar{J}$ | S | T | $\bar{U}$ | X | V | W | $\bar{Y}$ | $\bar{B}$ | E | K | F | G | H | | |
| 225- | $\bar{A}$ | $\bar{O}$ | I | $\bar{J}$ | S | T | $\bar{U}$ | V | W | $\bar{Y}$ | B | $\bar{E}$ | $\bar{K}$ | F | G | H | | | |
| 226- | $\underline{\bar{A}}$ | $\underline{\bar{O}}$ | I | $\underline{\bar{J}}$ | S | T | U | V | $\bar{W}$ | B | $\bar{E}$ | $\bar{F}$ | $\underline{G}$ | L | M | | | | |
| 227- | | | | | S | T | U | X | V | $\bar{W}$ | | | | | | | | | |
| 228- | | | | | S | T | $\bar{U}$ | X | V | W | Y | | | | | | | | |
| 229- | | | | | S | T | $\bar{U}$ | V | W | $\bar{Y}$ | | | | | | | | | |
| 230- | $\underline{A}$ | $\underline{O}$ | I | $\underline{J}$ | S | T | U | V | $\bar{W}$ | B | $\underline{E}$ | K | F | $\underline{G}$ | L | M | | | |
| 231- | | | | | S | T | U | X | V | $\bar{W}$ | | | | | | | | | |
| 232- | | | | | S | T | $\bar{U}$ | X | V | W | Y | | | | | | | | |
| 233- | | | | | S | T | $\bar{U}$ | V | W | $\bar{Y}$ | | | | | | | | | |
| 234- | $\underline{A}$ | $\underline{O}$ | I | $\underline{J}$ | S | T | U | V | $\bar{W}$ | B | E | F | $\underline{G}$ | $\underline{L}$ | N | M | | | |
| 235- | | | | | S | T | U | X | V | $\bar{W}$ | | | | | | | | | |
| 236- | | | | | S | T | $\bar{U}$ | X | V | W | Y | | | | | | | | |
| 237- | | | | | S | T | $\bar{U}$ | V | W | $\bar{Y}$ | | | | | | | | | |
| 238- | $\underline{A}$ | $\underline{O}$ | I | $\underline{J}$ | S | T | U | V | $\bar{W}$ | B | $\underline{E}$ | K | F | $\underline{G}$ | $\underline{L}$ | N | M | | |
| 239- | | | | | S | T | U | X | V | $\bar{W}$ | | | | | | | | | |
| 240- | | | | | S | T | $\bar{U}$ | X | V | W | Y | | | | | | | | |
| 241- | | | | | S | T | $\bar{U}$ | V | W | $\bar{Y}$ | | | | | | | | | |
| 242- | $\underline{A}$ | $\underline{O}$ | I | $\underline{J}$ | S | T | U | V | $\bar{W}$ | B | E | F | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | O | | |
| 243- | | | | | S | T | U | X | V | $\bar{W}$ | | | | | | | | | |
| 244- | | | | | S | T | $\bar{U}$ | X | V | W | Y | | | | | | | | |
| 245- | | | | | S | T | $\bar{U}$ | V | W | $\bar{Y}$ | | | | | | | | | |
| 246- | $\underline{A}$ | $\underline{O}$ | I | $\underline{J}$ | S | T | U | V | $\bar{W}$ | B | $\underline{E}$ | K | F | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | O | |
| 247- | | | | | S | T | U | X | V | $\bar{W}$ | | | | | | | | | |
| 248- | | | | | S | T | $\bar{U}$ | X | V | W | Y | | | | | | | | |
| 249- | | | | | S | T | $\bar{U}$ | V | W | $\bar{Y}$ | | | | | | | | | |
| 250- | $\underline{A}$ | $\underline{O}$ | I | $\underline{J}$ | S | T | U | V | $\bar{W}$ | B | E | F | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | $\underline{O}$ | R | |
| 251- | | | | | S | T | U | X | V | $\bar{W}$ | | | | | | | | | |
| 252- | | | | | S | T | $\bar{U}$ | Y | V | W | Y | | | | | | | | |
| 253- | | | | | S | T | $\bar{U}$ | V | W | Y | | | | | | | | | |
| 254- | $\underline{A}$ | $\underline{O}$ | I | $\underline{J}$ | S | T | U | V | $\bar{W}$ | B | $\underline{E}$ | K | F | $\underline{G}$ | $\underline{L}$ | N | $\underline{M}$ | $\underline{O}$ | R |
| 255- | | | | | S | T | U | X | V | $\bar{W}$ | | | | | | | | | |
| 256- | | | | | S | T | $\bar{U}$ | X | V | W | Y | | | | | | | | |
| 257- | | | | | S | T | $\bar{U}$ | V | $\underline{W}$ | $\bar{Y}$ | | | | | | | | | |

Steps 258 Thru 514, Repeat Steps 1 Thru 257 Replacing ($\underline{B}$) By ($\underline{C}$)

## TABLE 3-4
## RELIABILITY EQUATION FOR THE NEW TERMINATION UNIT DESIGN

$$
\begin{aligned}
R_{ns} &= X^3 + X^3(1 - X) + X^4(1 - X)^2 \\
&+ 2X^5(1 - X) + 6X^5(1 - X)^2 + 8X^5(1 - X)^3 \\
&+ 8X^5(1 - X)^4 + 6X^5(1 - X)^5 + 2X^5(1 - X)^6 \\
&+ 2X^6(1 - X)^3 + 4X^6(1 - X)^4 + 4X^6(1 - X)^5 \\
&+ 4X^6(1 - X)^6 + 2X^6(1 - X)^7 + 2X^7(1 - X)^5 \\
&+ 4X^7(1 - X)^6 + 2X^7(1 - X)^7 + 3X^8(1 - X)^3 \\
&+ 10X^8(1 - X)^4 + 14X^8(1 - X)^5 + 18X^8(1 - X)^6 \\
&+ 24X^8(1 - X)^7 + 24X^8(1 - X)^8 + 16X^8(1 - X)^9 \\
&+ 10X^8(1 - X)^{10} + 6X^8(1 - X)^{11} + 2X^8(1 - X)^{12} \\
&+ 2X^9(1 - X)^2 + 10X^9(1 - X)^3 + 22X^9(1 - X)^4 \\
&+ 35X^9(1 - X)^5 + 46X^9(1 - X)^6 + 52X^9(1 - X)^7 \\
&+ 46X^9(1 - X)^8 + 34X^9(1 - X)^9 + 22X^9( - X)^{10} \\
&+ 10X^9(1 - X)^{11} + 2X^9(1 - X)^{12} + 4X^{10}(1 - X)^4 \\
&+ 16X^{10}(1 - X)^5 + 28X^{10}(1 - X)^6 + 32X^{10}(1 - X)^7 \\
&+ 32X^{10}(1 - X)^8 + 28X^{10}(1 - X)^9 + 16X^{10}(1 - X)^{10} \\
&+ 4X^{10}(1 - X)^{11}
\end{aligned}
$$

## TABLE 3-5
## SIMPLIFIED EQUATION FOR THE NEW TERMINATION UNIT DESIGN

| X=Rs | Rns |
|---|---|
| .3 | .073 |
| .4 | .181 |
| .5 | .393 |
| .6 | .550 |
| .7 | .752 |
| .8 | .902 |
| .82 | .927 |
| .84 | .946 |
| .86 | .961 |
| .88 | .973 |
| .90 | .988 |
| .92 | .991 |
| .94 | .995 |
| .96 | .998 |
| .98 | .9995 |
| .999 | .999999 |
| 1.0 | 1.0 |

$$
\begin{aligned}
R_{ns} \quad & X^3 + X^3(1-X) + X^4(1-X)^2 + 2X^5(1-X) \\
& 6X^5(1-X)^2 + 8X^5(1-X)^3 + 8X^5(1-X)^4 \\
& + 2X^6(1-X)^3 + 4X^6(1-X)^4 + 3X^8(1-X)^3 \\
& + 10X^8(1-X)^4 + 2X^9(1-X)^2 + 10X^9(1-X)^3 \\
& + 22X^9(1-X)4 + 4X^{10}(1-X)^4
\end{aligned}
$$

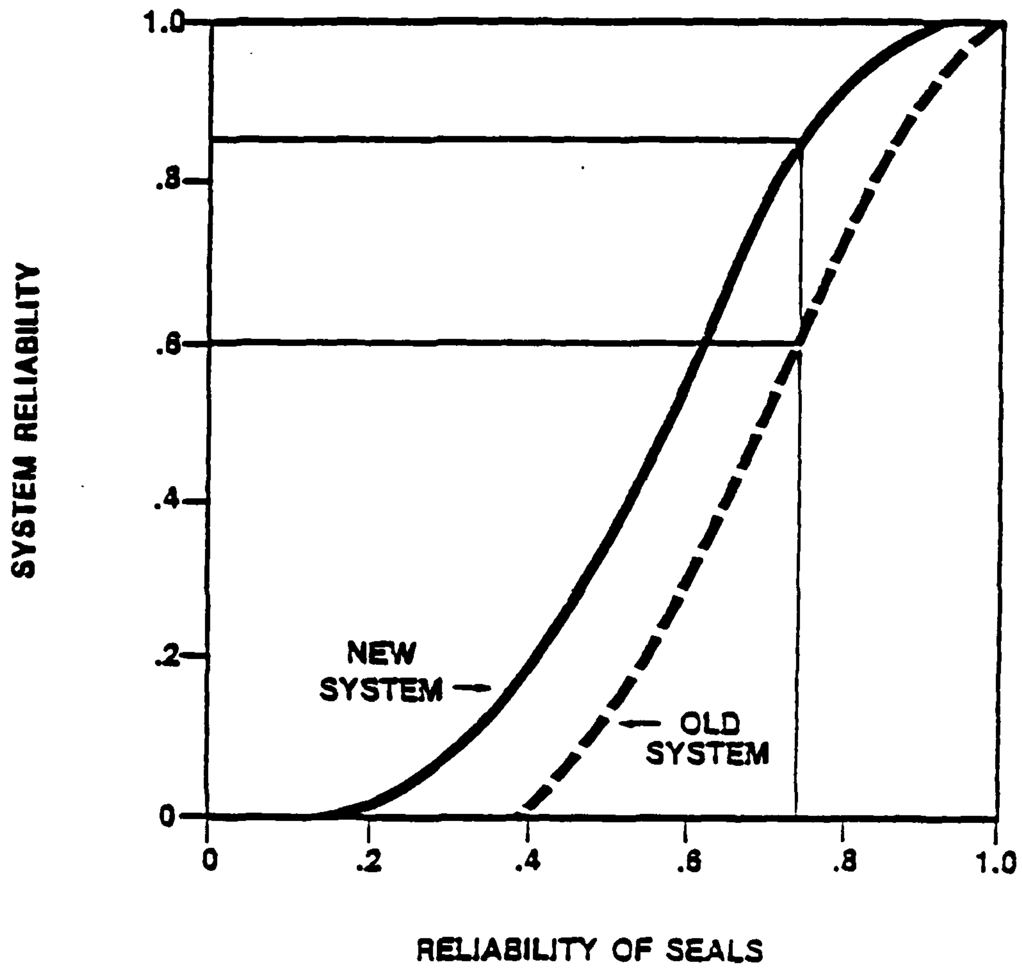



Figure 3-4. Reliability Comparison of the Original and New Designs

## 4. INTEGRATED TEST PROGRAM

This section describes a recommended program of testing that will provide a degree of assurance (both quantitative and qualitative) that the termination unit, as designed, fabricated, assembled and deployed, will perform successfully for the duration of its mission and will not lead to system degradation or failure. The topics covered in this section include the Test Objectives, Provisional Definition of System Failure, and the Test Plan.

### 4.1 Test Objectives

The objectives of the integrated test program are first to provide assurance that the termination unit will be capable of operating maintenance free for a period of twenty years, and second to identify any potential problem area in the design, handling, transportation, assembly and storage, and deployment of the termination unit.

### 4.2 Provisional Definition of System Failure

In order to properly develop the test plan and satisfy the test objectives, the relationship between failure of a termination unit and the BSURE system must be analyzed and quantified. The following discussion relates the termination unit failure to system failure and offers a definition of system failure to be used only for purposes of developing a test plan.

The failure of a single termination unit does not necessarily consitute a BSURE system failure. Since the system is designed with two strings of nine TATUs in series, a termination unit failure will impact system performance differently depending on where the failure occurs along the string. A failure of the unit nearest the shore in a string will result in a loss of the entire string. A failure of the unit furthest from shore in a string will not affect any other units. For the purposes of this analysis, the system is said to be in a failed condition if four or more TATUs are inoperative.

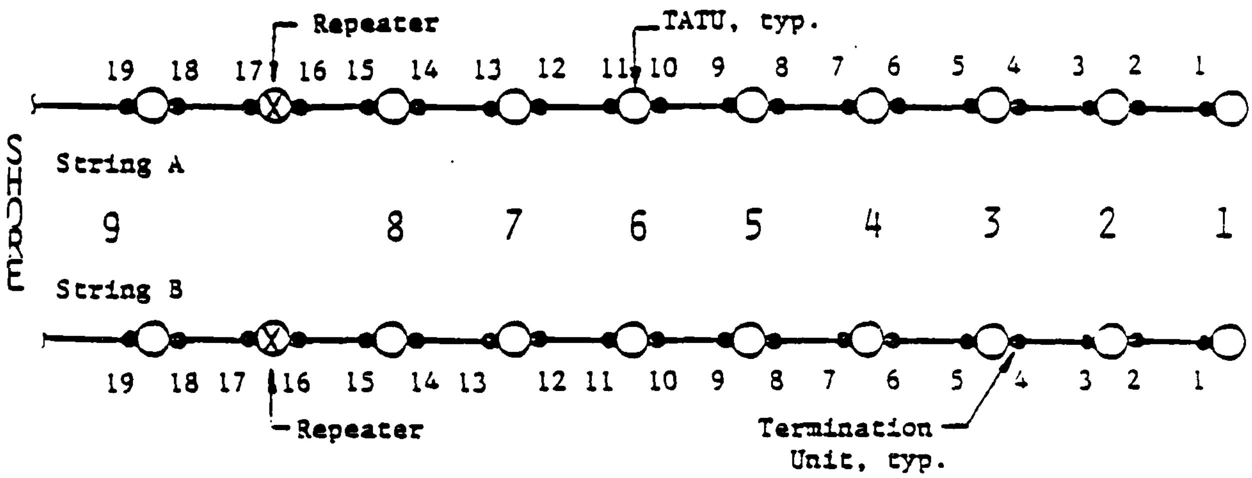
A summation of operate time for the termination units in the in-water BSURE system totals $1.945 \times 10^6$ hours. Because of the design of the original unit, this operate time can also be applied to the Morrison seal around the SD cable. To determine the reliability of this Morrison seal, operate time was rounded to $2.0 \times 10^6$ and one failure was assumed. A twenty-year life was the desired goal. Hence,

$R = e^{-\lambda t} = 0.916$ where,
$\lambda$ = number of failures/system time = $1/(2 \times 10^6)$
$t$ = 175,200 hours (20 years)

The reliability of all seals and O-rings has been assumed the same. Thus, the probability of survival for each O-ring and seal is 0.916. When this part reliability (rounded to 0.92) is put in the reliability equation for the new termination unit design, the reliability is computed to be 0.991. Thus, the probability that any given termination unit will survive twenty years is 0.991. Using a termination unit reliability of 0.99 the following table shows the probability of unit failure.

| n = Number of Termination Units Failing | P(n) |
|---|---|
| 0 | .6826 |
| 1 | .2620 |
| 2 | .0490 |
| 3 | .0059 |
| 4 | .0005 |

For purposes of this analysis it has been assumed that a system failure occurs if a total of four or more TATUs fail to operate on either string. The two strings are structured as indicated by the following schematic:




Each TATU is attached to the cable by means of a termination unit on each end. A failure of a termination unit will cause the loss of all TATUs to the seaward side of that unit. For instance, the failure of termination unit A4 will cause the loss of TATUs A2 and A1. The failure of termination unit A5 will cause the system to lose TATUs A3, A2, and A1.

Based on the preceding definition a termination unit failure may be "critical" (cause a system failure) or non-critical. The following table shows the probability of a critical failure as one or more unit failures occur.

| Number of Termination Unit Failures | P (failure is critical) |
|---|---|
| 1 | .6842 (26/38) |
| 2 | .9403 (661/703) |
| 3 | .9924 (8372/8436) |
| 4 | .9992 (73755/73815) |

Multiplying the probability that a given number of units fail times the probability that those failures are critical, yields the probability that a system failure will occur.

| P (No. of Unit Failures) | X | P (Failure is Critical) | = | P (System Fails) |
|---|---|---|---|---|
| (P (1) = .2620) | X | (P ($F_1$) = .6842) | = | .1793 |
| (P (2) = .0490) | X | (P ($F_2$) = .9403) | = | .0460 |
| (P (3) = .0059) | X | (P ($F_3$) = .9919) | = | .0059 |
| (P (4) = .0005) | X | (P ($F_4$) = .9992) | = | .0005 |
| TOTAL | | | | .2317 |

Thus, the probability that one, two, three, or four termination failures occur and that these failures are critical is 0.2317. Conversely, the probability that zero to four termination unit failures occur without causing a system failure is 1 - 0.2317 or 0.7683. Hence, based on the above stated assumption, the probability that the system will survive twenty years is 0.7683 where survival is defined as having at least 15 TATUs operating. It should be noted that this analysis covers only the sealing system of the termination unit. Probability of survival would be somewhat reduced if other aspects of the system, such as electronics, were included in this analysis.

### 4.3 Test Plan

The plan to test the termination units includes four types of tests: reliability/TAAF tests, environmental stress tests, accelerated aging tests, and assembly tests. Table 4-1 is a synopsis of these tests and provides the objective, anticipated duration, required hardware, parameters, and references for each test. The following four paragraphs discuss each of these tests in more detail.

4.3.1 Reliability/TAAF Tests. MIL-STD-781 prescribes the reliability tests to be performed on military systems and equipment. These tests are used to determine the probability that the system or equipment being tested will achieve a specified MTTF. The duration of these tests is in multiples of specified MTTF. The BSURE system includes 42 termination units each designed for 20 years of operation. Of the 42 units, only 38 can contribute to system failure. (In this analysis we are only dealing with the sealing system which operates continuously after deployment, whether the range is being operated or not.) Therefore the total operate hours are: 38 units x 8760 hours per year x 20 years or 6,657,600 hours. Thus, the specified MTTF of a unit should be close to 6.7 million hours to achieve an expected range life of 20 years. For items with extremely high MTTF, such as the termination unit, the tests in MIL-STD-781 do not apply because test times are in multiples of the specified MTTF. It is, of course, impractical to test the unit to millions of operate hours. Since the usual reliability test methods are not practical, other test techniques have been examined to determine if any of them could provide some assurance of termination unit reliability performance.

The most promising reliability test for this situation is the Bayes test. This test permits the use of operational data if the unit being tested is at least as reliable as the unit from which operational data is being used. As was shown in Section 3 of this report the new termination unit design is inherently move reliable than the original design. Since this is the case, a Bayes test allows operational data on the original design to be combined with reliability test data on the new design to predict the reliability of the new design. In order to do this, however, certain criteria must be satisfied. First, none of the BSURE failures can be attributed to the system analyzed, i.e., the sealing system for the new termination unit. Second, there has to be reasonable assurance that no new failure mechanisms have been introduced via the new design. The BSURE range has been operated for approximately five years without experiencing a unit failure that can be attributed to an O-ring or a Morrison seal failure. Three types of failures have occurred on the BSURE range. The first type was seawater leaking between the SD cable polyethylene sheath and the Morrison seal. Upon inspection, it was determined that this failure was caused by grooves in the polyethylene

TABLE 4-1
SYNOPSIS OF RECOMMENDED TESTS

| Type of Test | Objective | Duration | Required Hardware | Parameters | References |
|---|---|---|---|---|---|
| Reliability/TAAF Test | To determine the reliability of the unit sealing system and to detect and fix any inherent deficiencies in design, manufacture, and assembly | 2400 Hours | Two unit completely and properly assembled | Length of continuous successful operation | MIL-STD-781, Design of Reliability Test Plans based on Prior Distribution |
| Stress Tests | To stress the unit sealing system in ways that represent the worst conditions to the which unit is expected to be subjected | 3 Months | Assembled Unit | Capability of the units sealing system after being subjected to defined stress conditions | MIL-STD 810-C |
| Accelerated Aging Tests | To predict the effects of aging on all components of the sealing system | 2 Years | All silicon and and butyl components | Physical properties of silicon and butyl components after simulated aging in moist air, seawater, and castor oil | None |
| Assembly Tests | To identify inherent deficiencies in the termination unit procedures | 2 Weeks | One unit with a spare set of rubber components | Condition of silicon and butyl components after being assembled in accordance with approved procedures | None |

sheath resulting from the manufacturing process. The new assembly procedure calls for eliminating these grooves by machining. It appears, therefore, that this failure was not caused by failure of the Morrison seal but rather by inadequate assembly procedures. The second type of failure was due to a torque applied to an off center pin that ran through the cup seal. The torquing destroyed the seal around the pin and allowed seawater to penetrate. This pin has been eliminated in the redesign of the termination unit. In the third type of failure, an SD cable pulled out of termination. This was obviously not caused by a Morrison seal or an O-ring. It appears, therefore, that we can justifiably assume that during the BSURE operation there has not been a failure of the termination unit sealing system. This represents about $2X10^6$ hours of failure-free operation of the termination unit sealing system.

The second criteria (no new failure mechanisms introduced via the new design) is impossible to justify now. However, at some point in the test program it will be possible to detect inherent flaws in the new design or in the manufacture, assembly, etc. of the components.

At this point various Bayes test plans were examined to identify those that appeared applicable to the BSURE system. It was discovered that no reliability testing would be required if the Government accepts a ten percent average consumers risk. This means that the Government accepts a ten percent risk defined by the fraction: $\frac{\text{Number of bad systems accepted}}{\text{Total number of bad systems tested}}$.

This is a fairly reasonable risk and CRC recommends its acceptance by the Government. Since no reliability tests are required, CRC recommends that a reliability/TAAF test be performed to examine the postulate that no inherent design flaws exist in the unit. CRC recommends that two properly assembled units representing production units be tested in simulated deployment conditions for fifty days each, or a total of 2400 operate hours. With an MTTF of about $5 \times 10^6$ hours, the unit is expected to function failure-free over the test period. Therefore if any failures occur during the test, the test should be terminated and a complete failure analysis should be conducted. The failure analysis will indicate the necessity for a design and/or procedure change. The indicated changes should be incorporated into two new units and the tests should begin all over again. This process should continue until the entire test duration is completed without experiencing a failure of the termination unit sealing system.

4.3.2 Environmental Stress Tests. Environmental stress tests are used to determine the capability of the unit to withstand the normal stresses it is expected to encounter from the time it is manufactured through its operational service life. Table 4-2 lists the environmental conditions that the termination unit is expected to encounter, and Table 4-3 lists a series of environmental stress tests that should be conducted on the unit.

Eleven tests are recommended as shown in Table 4-3. Detailed description of the first ten tests may be found in MIL-STD-810C. The pressurization test is described in the 100 Percent Design Plan.

4.3.3 Accelerated Aging Tests. Since the termination unit is expected to function for twenty years, it was decided to examine the possibility of conducting accelerated aging tests on the Morrison seals and O-rings. Accelerated aging tests do not accurately predict when the components will fail. All they really do is identify the failure modes that will occur due to

TABLE 4-2
TERMINATION UNIT MISSION PROFILE ENVIRONMENTAL CONDITIONS

| Mission Phase | Temperature | Vibration | Shock | Humidity | Tension | Torsoon |
|---|---|---|---|---|---|---|
| Storage | $40^{o}$ F - $120^{o}$F | N/A | N/A | 0-100% | N/A | N/A |
| Ground Transport | $20^{0}$ F - $110^{o}$F | 0-500Hz | 4 FT. Drop | 0-100% | N/A | N/A |
| Gimbal Assembly | $60^{o}$ F - $100^{o}$F | N/A | 4 FT. Drop | 0-100% | N/A | N/A |
| Shipboard Transport | $40^{o}$ F - $110^{o}$F | NOTE | 4 FT. Drop | 0-100% | N/A | N/A |
| Assembly | $40^{o}$ F - $110^{o}$F | N/A | 4 FT. Drop | 0-100% | 5000 lbs | ± 12ft-lbs |
| Deployment | $40^{o}$ F - $110^{o}$F | NOTE | 4 FT. Drop | 0-100% | N/A | N/A |
| Operation | $4^{o}$C | NOTE | 4 FT. Drop | 0-100% | N/A | ± 12ft-lbs |

NOTE: See MIL-STD-167

TABLE 4-3
ENVIRONMENTAL STRESS TESTS

| METHOD | TEST | REMARKS |
|---|---|---|
| # 501.1 | High Temperature | This test is used to determine the effects of high temperature on the termination. The test should be conducted with an unpressurized and a pressurized termination. |
| # 502.1 | Low Temperature | This test is conducted to determine the effects of low temperature on the equipment during storage. |
| # 503.1 | Temperature Shock | This test simulates possible deployment conditions. |
| # 507.1 | Humidity | This test is conducted on silicon and butyl components only to determine the amount of moisture absorbed by these component and long term effects. |
| # 508.1 | Fungus | This test is used to determine the resistance of the equipment to fungus. |
| # 509.1 | Salt Fog | This test is conducted to determine the the effects of a salt atmosphere on the equipment. |
| # 510.1 | Dust | This test is used to determine the effects of dust on the equipment, particularly the effects of dust on equipment assembly. |
| # 512.1 | Leakage | A modification of this test could be used to determine the integrity of the seals after pressurizing and just prior to deployment. |
| # 514.2 | Vibration | This test is used to determine if the equipment is capable of withstanding the vibration encountered during handling and transportation. |
| # 516.2 | Shock | This test is performed to determine the capability of the equipment to withstand the shock stresses likely to be encountered during its life cycle. |
| — | Over Pressurization | This test is performed to demonstrate the integrity of the seals after termination unit assembly. |

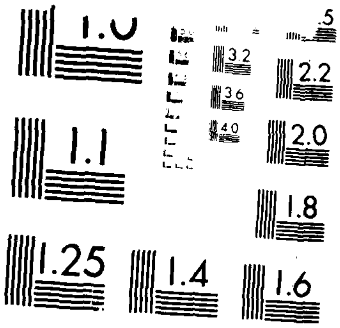
the aging process. Only after extensive testing can an accurate correlation be made between induced and actual aging.

Accelerated aging tests are usually based on a rule of thumb that says, "an increase of 10°C doubles the aging rate." Applying this rule, an accelerated aging test plan was developed for the termination unit sealing components. This plan is summarized in Figure 4-1. The verticle axis in the figure is storage temperature in degrees centigrade, and the horizontal axis is storage time shown in both years and days. The family of curves in the figure represents equivalent ages. The curve at the left, for instance, represents the possible ways of storing a component to achieve an equivalent age of two years. Following this curve upward, it can be seen that this first point indicates that storing a sample at 14°C for one year is equivalent to two years of actual operation at 4°C. The next point shows that storing the components for 180 days at 24°C is also equivalent to two years of actual operation at 4°C. As shown in the figure, it is then planned to conduct tests for equivalent ages of 2, 4, 6, 8, 10, 15, and 20 years. A total of 19 test points is recommended resulting in a total test duration of approximately two years. According to current planning, this will permit all the accelerated aging tests to be conducted prior to system deployment. That way, if serious aging problems are anticipated due to testing, a fix can be incorporated prior to deployment. For each of the 19 sample withdrawals, a control sample should also be withdrawn permitting a direct comparative analysis between actual and equivalent ages. Also, as indicated in the figure, the samples should be tested in oil, seawater, and moist air thus giving a total test sample size of 57 with 57 control samples. After withdrawal, each sample should be inspected and tested to determine: weight change, elastic modulus, hardness, ID, OD, roundness, and surface condition.

4.3.4 <u>Assembly Test</u>. The termination unit should be subjected to tests to determine what effects assembly will have on unit performance. Particularly, the effects of assembly on the condition of the Morrison seals and O-rings should be determined. Assembly tests should be conducted on both the gimbal side and the SD cable side. In these tests, the unit should be assembled under conditions that simulate, as closely as possible, the actual assembly conditions including skill levels of assembly technicians. All components should be thoroughly inspected prior to assembly. The unit should then be carefully disassembled by the most skilled individual. After disassembly, the components should be visually and microscopically examined to determine if the assembly procedure causes component damage.

AD-A168 658 CABLE TERMINATIONS FOR THE BSURE (BARKING SANDS UNDERWATER RANGE EXPANSIO..(U) NAVAL FACILITIES ENGINEERING COMMAND WASHINGTON DC CHESAPEAKE.. 1985 3/3

UNCLASSIFIED CHES/NAVFAC-FPO-1-85(12) F/G 13/10.1 NL




MICROCOPY RESOLUTION TEST CHART

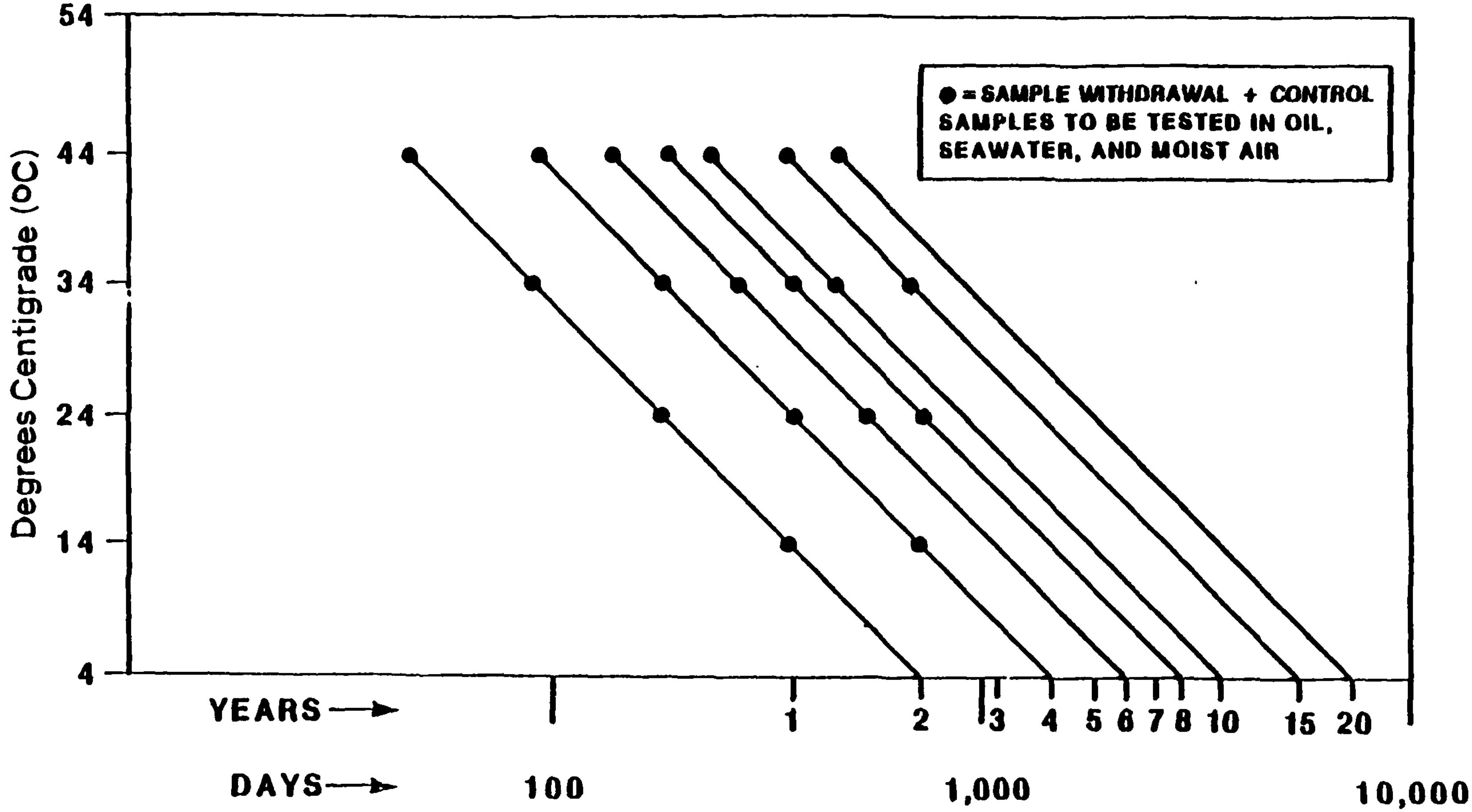



Figure 4-1. Test Plan for Accelerated Aging

## 5. CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Reliability of New Design

From the reliability analysis, it has been concluded that the new termination unit design is a significant improvement over the original design. The predicted improvement is a result of increased component redundancy in the new design. Additional performance improvement should result from the fact that the unit has been redesigned to eliminate pressure differentials across all seals except one. The beneficial effects of eliminating the pressure differential were not considered in our reliability analysis. Based on this conclusion, it is recommended that the currently designed termination unit be approved for use in the BSURE and that no further design efforts be conducted unless the need for redesign is subsequently indicated by testing.

### 5.2 Testing of the New Design

Numerous development tests have been conducted on the termination unit as indicated on the 100 Percent Design Plan. These tests, however, were conducted a number of years ago prior to final design approval. In addition, no qualification tests have been conducted on the unit. It is recommended, therefore, that the tests described in Section 4 be conducted to determine the design integrity, adequacy of assembly procedures, and to verify expected system reliability. It is further recommended that the Government accept the ten percent average consumers risk described in paragraph 4.3.1. Acceptance of this risk by the Government eliminates the need for extensive reliability testing.

### 5.3 Test Planning

Lastly, it is recommended that the testing requirements for the termination unit be thoroughly examined in relationship to the design, development and implementation schedule, and that a detailed test plan be developed covering all phases and aspects of termination unit testing.

## GLOSSARY

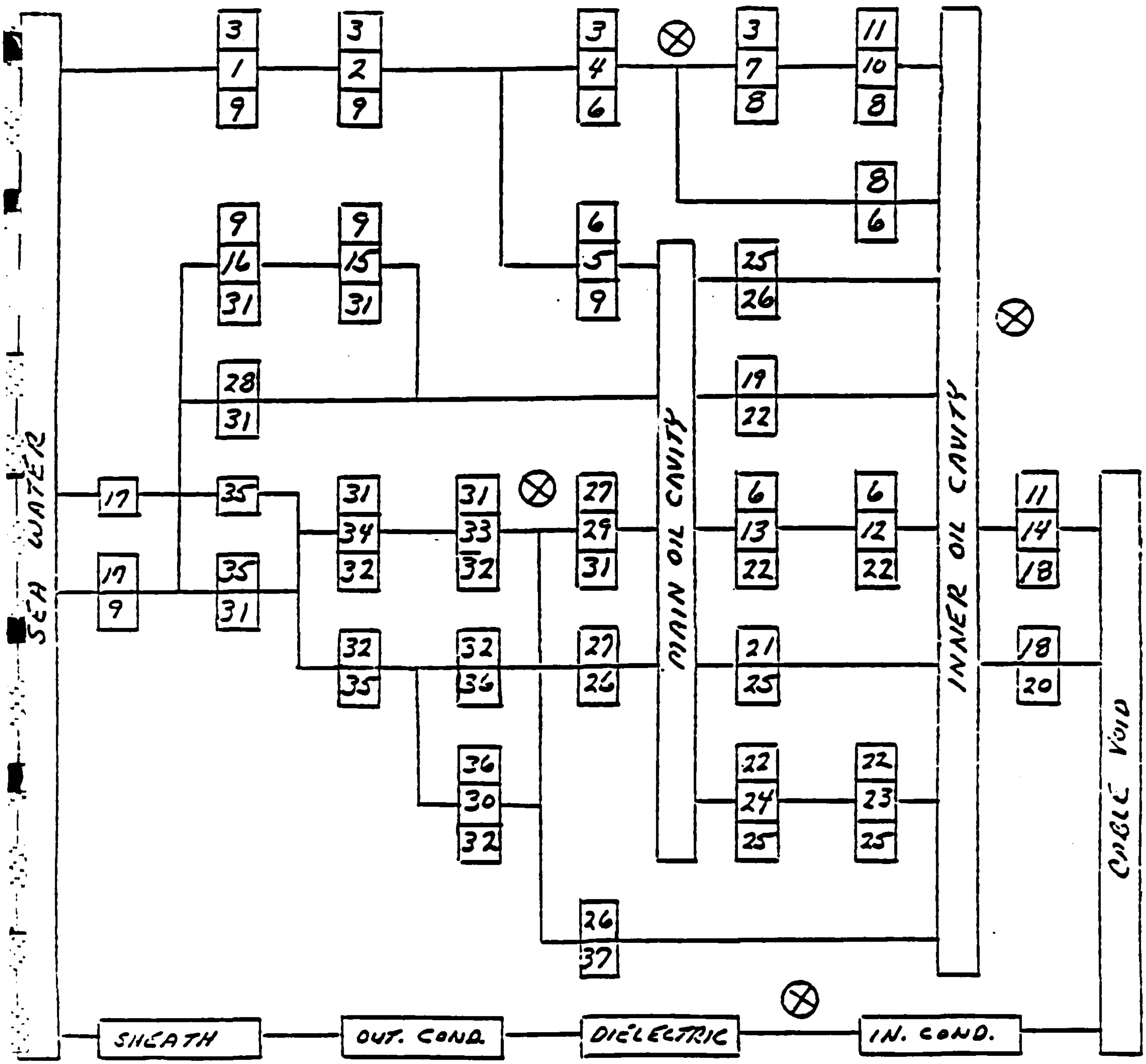
| | |
|---|---|
| BARSTUR | Barking Sands Tracking Underwater Range |
| BSURE | Barking Sands Underwater Range Expansion |
| FIT | Female Isolation Tube |
| ID | Inside Diameter |
| MIT | Male Isolation Tube |
| MTTF | Mean Time To Failure |
| NAVFACENGCOMCHESDIV | Naval Facilities Engineering Command, Chesapeake Division |
| OD | Outside Diameter |
| P(Fn) | Probability that the "n" failed termination units each occur in a critical location |
| PMTC | Pacific Missile Test Center |
| P(n) | Probability that any number, n, of termination units will fail |
| $R_{ns}$ | Reliability of New Design |
| $R_{od}$ | Reliability of Original Design |
| $R_s$ | Reliability of Seal |
| SD | (Prefix identifying type of submarine cable) |
| TAAF | Test Analyze and Fix |
| TATU | Termination and Transmission Unit |

APPENDIX I

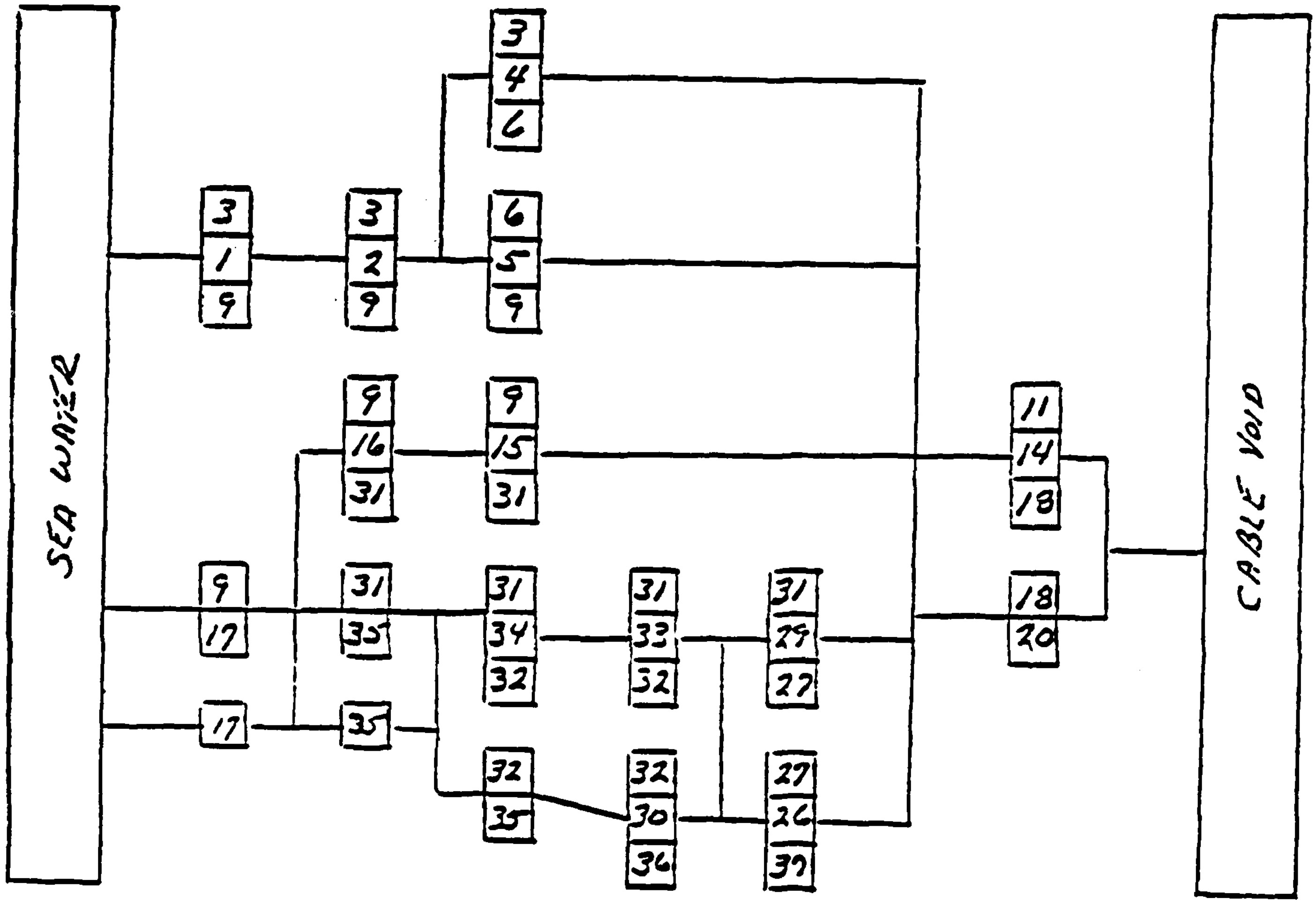
DESIGN/REDESIGN BLOCK DIAGRAMS FOR

LEAK PATH RELIABILITY ANALYSIS

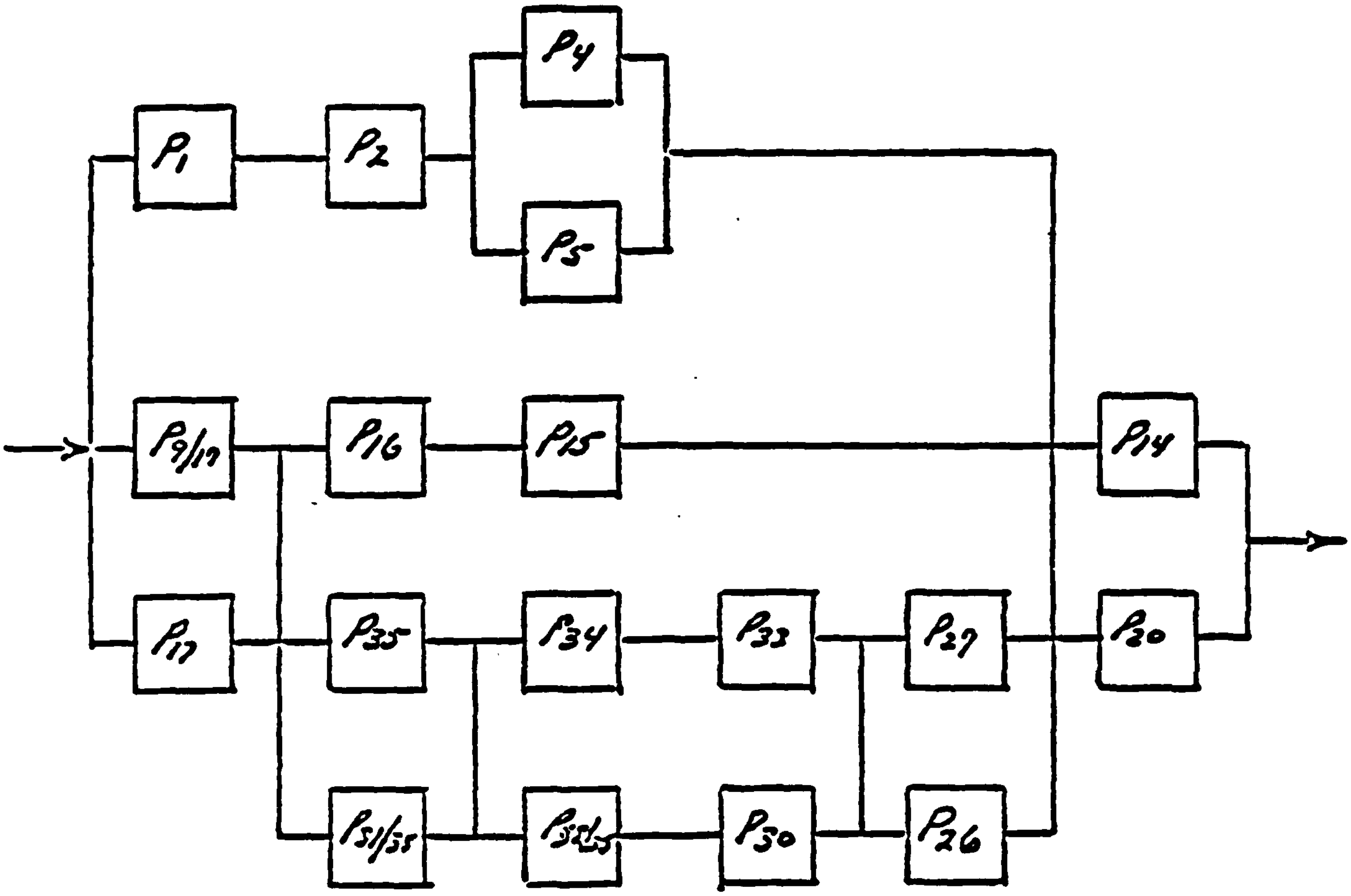
CHESNAVFACENGCOM



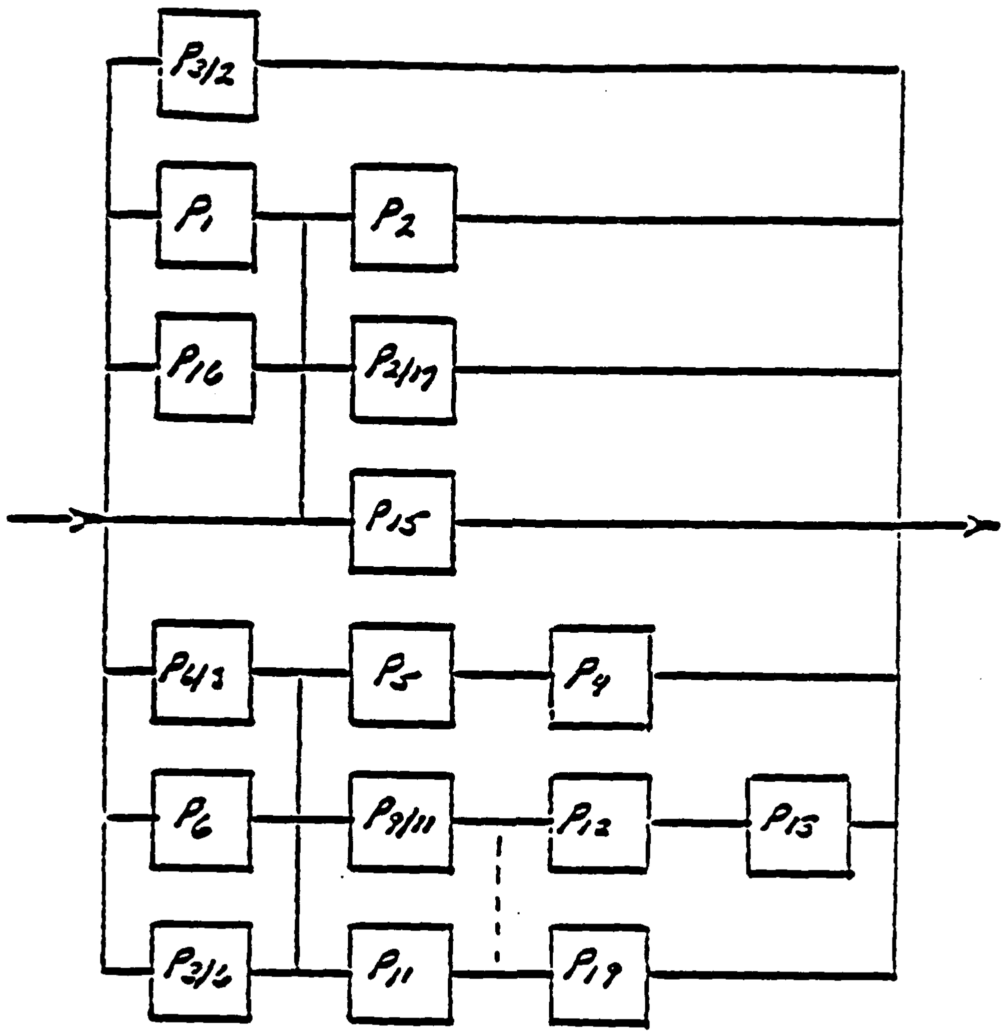

NEW DESIGN LEAK PATH DIAGRAM
(ADAPTED FROM PMTC FMEA)



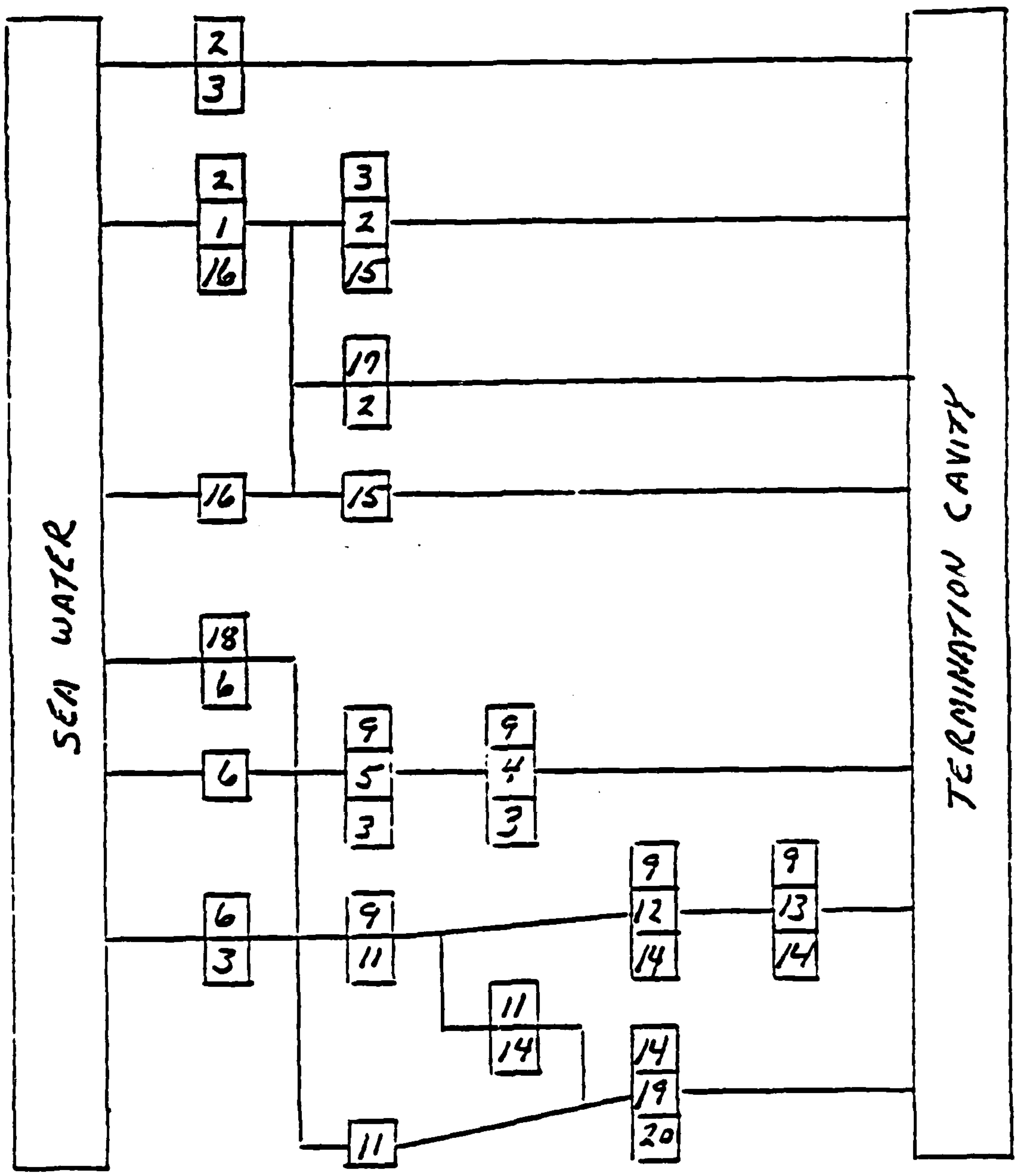

NEW DESIGN LEAK PATH DIAGRAM - SIMPLIFIED



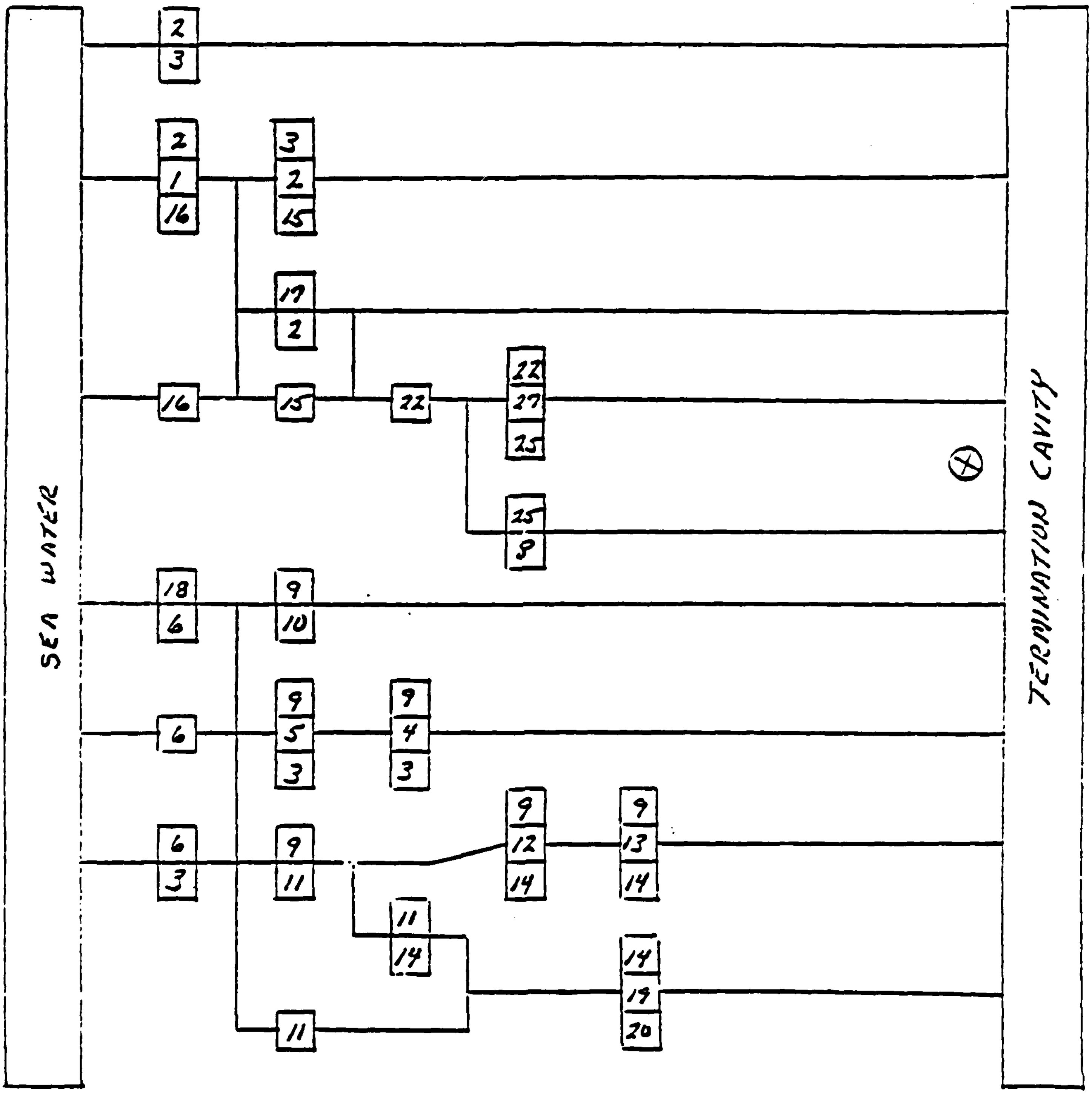

SIMPLIFIED RELIABILITY BLOCK DIAGRAM
(NEW DESIGN)




SIMPLIFIED RELIABILITY BLOCK DIAGRAM
(OLD DESIGN)




OLD DESIGN LEAK PATH DIAGRAM - SIMPLIFIED




OLD DESIGN LEAK PATH DIAGRAM
(FROM PMTC INFO)

# COMPARATIVE RELIABILITY EQUATIONS

ORIGINAL DESIGN

$$P_F = 1-(S)[1-(-S^2)(1-S^3)]\left\{1-(1-S^3)[1-(1-F^2)^2(1-F^3)]\right\}$$

IMPROVED DESIGN

$$P_{F1} = F^2(1-S^2)$$

$$P_{F2} = 1-S^3$$

$$P_{F3} = (1-S^2)\left\langle 1-[1-F^2]\left\{1-[1-S^2]^2\,[1-(1-F^2)^2]\right\}\right\rangle$$

$$P_F = [P_{F3}]\,[1-1-P_{F1})\,(1-P_{F2})]$$

F - Probability of failure

S - Probability of non-failure (success)

$F+S=1$

# PARAMETRIC RELIABILITY ANALYSES



| F | S | PF(OLD) | PF(NEW) | PF(OLD/PF(NEW) | S/F | N |
|---|---|---|---|---|---|---|
| .900 | .100 | .9979 | .9860 | 1 | 0.1 | 0.134 |
| .340 | .660 | .4633 | .8895 | 5 | 1.9 | 2.238 |
| .270 | .730 | .3711 | .0373 | 10 | 2.7 | 2.512 |
| .150 | .850 | .2076 | .0037 | 50 | 5.7 | 2.952 |
| .122 | .878 | .1667 | .00164 | 100 | 7.2 | 3.048 |
| .070 | .930 | .0898 | .00018 | 500 | 13.3 | 3.242 |
| .055 | .945 | .0683 | .00007 | 1,000 | 17.2 | 3.298 |
| .031 | .969 | .0356 | .000007 | 5,000 | 31.3 | 3.417 |
| .024 | .976 | .0270 | .0000026 | 10,000 | 40.7 | 3.448 |

F - PROBABILITY OF FAILURE OF A SINGLE SEAL OVER 20 YEARS

S - PROBABILITY OF NON-FAILURE OF A SINGLE SEAL OVER 20 YEARS (1-F)

$P_F$ - PROBABILITY OF FAILURE OF THE NEW SERIES/PARALLEL MULTI-ELEMENT SEAL OVER 20 YEARS

N - EQUIVALENT SERIES SINGLE SEALS THAT GIVES THE SAME RESULTS AS THE SERIES/PARALLEL MULTI-ELEMENT SEAL (N = LOG PF/LOG F)

END
DTIC
7 — 86